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House Magazines

It is only the larger concerns that can afford to publish house magazines, of which there are infinite variety. The best-known type is the one which " sells the firm to the firm," and does this by reporting all the social and sporting activities of the staff. If they go beyond these activities, there is a danger of diluting the main objectives, to the detriment of their functional value. When carefully edited, they can be of live interest and productive of much good. Where a firm's shops are scattered over a wide area, each one should be separately catered for, as, unless one knows the personnel of the various departments pretty intimately, the result is very much like an inhabitant of a Sussex township trying to interest himself in a local paper published in Cumberland. " Over departmentalism," by which is meant the unhealthy segregation of a large organisation into watertight compartments, can be effectively checked by means of well-produced magazines and the ideas of friendly rivalry with unity of purpose can be substituted. For this sort, the original object of " selling the firm to the firm " must always be kept in mind and every article must bear this imprint.

A second type has an entirely different scope. It " sells the firm's products to its customers." It restricts news of personnel to its officials—by introducing new representatives to its clientele and telling of the major business trips of its directors and so forth. Its main purpose, however, is to publicise new lines of manufacture and give service in connection with the firm's general products. There is an infinite number of varieties of these, and outstanding in usefulness are those issued by research and development departments of large firms and associations. A newish idea carried out by one of the largest concerns in the foundry industry is a magazine specially designed to interest its overseas representatives. It records, often pictorially, the visits of these agents to the works and does tend to engender a family atmosphere, where remoteness tends to estrangement.

There should be a recognition that these house magazines, though intended for private circulation, are in truth quite public, from the very fact that they are *printed*. Because of this, every care should be taken in their composition. Only recently we received one with a request to make an extract, but which was " blue pencilled " in certain sections. Whilst we respected the proviso we do suggest that if the matter published was likely to be damaging if reproduced in a national paper, it should not be printed in a house organ. The type of magazine which fails to impress us is the one wholly or partially financed by the firm's suppliers. It is not, to our mind, good business to take advertisements from concerns from which supplies are drawn. If the buyer wishes to change his source of supply there is the complication of a contra account. Whilst house magazines can be productive of much good, they can be a distinct nuisance, and before any firm undertakes such a project they should endeavour to produce the third or fourth issue in embryo before launching the first.

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Steel for Castings

The British Iron and Steel Research Association, 11, Park Lane, London, W.1, have organised a conference on the above subject, to be held at Ashorne Hill, Leamington Spa, on September 22 and 23. The chairman is to be Mr. Richard Lamb. There will be four sessions. The first—"The Cupola/Converter" Process—is to be made up of Papers by Mr. F. Cousans (Hadfields, Limited); Mr. A. G. Robbiette (John Miles & Partners (London), Limited); Mr. A. J. Langner (B.I.S.R.A.), and Dr. W. C. Newell (B.I.S.R.A.). The "Electric-arc Process" is the subject of the second session, and the lecturers are Mr. J. H. Pearce and Mr. W. Bramhall (English Steel Corporation, Limited); Dr. J. R. Rait (Hadfields, Limited); Mr. J. C. Howard (Electric Furnace Company, Limited), and Mr. F. A. Martin, O.B.E. (Samuel Osborn & Company, Limited).

The second day opens with a morning devoted to "Other Melting Processes," and the speakers are to be Mr. A. C. Brearley (K. & L. Steelfounders, Limited); Mr. C. McNair (Hadfields, Limited), and Mr. J. Mowat (William Beardmore & Company, Limited). The final session—"General Items"—includes Papers on fluidity, by Mr. J. E. Worthington (B.I.S.R.A.); on costs by Mr. F. N. Lloyd (F. H. Lloyd & Company, Limited), and on specifications, by Dr. E. Gregory (Edgar Allen & Company, Limited). Full details are available by writing to Mr. R. W. Berry at 11, Park Lane, London, W.1.

The Passing of a Pioneer

We regret to announce the death of Mr. Robert Mason, the last survivor of those eight foundrymen who met in Birmingham in 1904 and decided to form the British Foundrymen's Association, later to become the Institute of British Foundrymen. For several years he was a particularly active member, but because of his wife's health, he went to Adelaide, South Australia. Here he founded the firm of Mason & Cox, Limited. This foundry and light-engineering concern, under his direction, has made continuous progress. He visited this country in 1929, and participated in an international foundry conference. He died in Adelaide last Monday in his 85th year. He was a man of considerable charm, retiring, modest, but withall a pioneer of a type which, unfortunately, is becoming a *rara avis*.

Index to Volume 86

The index to Volume 86 (January to June) of the FOUNDRY TRADE JOURNAL is now ready. Copies are available, *gratis*, upon application to the Publisher, FOUNDRY TRADE JOURNAL, 49, Wellington Street, Strand, London, W.C.2.

OERLIKON, OF ZURICH, are proposing to establish in India a factory for the manufacture of machine tools. It will take four years to build and will operate with a capital of Rs. 12 crores (£9 million).

International Scientific Film Association

The third International Scientific Film Congress will be held in Brussels from September 30 to October 5. During the time, delegations from many countries will meet to discuss progress on various subjects of importance in relation to the international aspect of scientific films. Sub-committees will be presenting reports on such projects as the establishment of a standard method for cataloguing and recording information about scientific films and on customs regulations in relation to their international exchange.

In conjunction with the Congress, there will be a Scientific Film Festival. This will include four public sessions with films dealing with research, education and scientific documentary. The fourth show will consist of general scientific films. In addition to the public shows, there will be four sessions for specialists. The fields covered in this section will include research, education and industry.

The Scientific Film Association of Great Britain is considering the films to be submitted as the British entry in the Festival. Whilst the Association has knowledge of most of the major films, it would appreciate information regarding privately-produced films which might be suitable for inclusion. Full details should be sent to the office of the Association at 4, Great Russell Street, London, W.C.1.

Stanton Amenities Extended

With the opening on August 9 of another ablution centre at Stanton Ironworks Company, Limited, improved washing and toilet facilities are available for still more of the company's employees.

The Mayor of Ilkeston, Councillor J. C. Britton, an employee in the Stanton Old Works machine shop, who opened the centre, referred to the great improvement in the workmen's conditions from his own early days. Introducing Councillor Britton, Mr. P. H. Wilson, O.B.E., deputy managing director, described the amenities which the Stanton Ironworks has provided for its employees, and referred to the ambulance stations with nursing sisters, the full-time medical and dental officers, and the physiotherapy department. Visitors to the opening ceremony included Miss Reid, H.M. Inspector of Factories; Mr. W. E. Ludlam, National Union of General and Municipal Workers; Mr. E. Adams, M.B.E., ex-Mayor of Ilkeston, who is also a Stanton employee, and officials of the company.

The centre is designed to cater for some 600 men, each of whom will be allocated a private locker with an individual key. There are 32 shower-baths in four batteries of eight and four circular fountain-spray washbowls complete with automatic soap supply. At each of these, eight men can wash simultaneously and then dry their hands by means of foot-operated hot-air dryers which avoid the use of hand-towels. In addition, this centre has ample lavatory accommodation for this large number of men, and the whole is contained in a centrally-heated building 84 ft. by 41 ft. 6 in. wide, with a concrete roof and anti-slip granolithic floor.

Effect of Stripping Temperature on the Properties of Pearlitic Grey Cast Iron*

Report of Sub-committee T.S. 18 of the I.B.F., Technical Council

Terms of Reference

With increasing rates of production, particularly in mechanised foundries, there is a tendency for castings to be stripped from the mould soon after they have been poured, and while they are still at relatively high temperatures. Following variations in the properties of certain iron castings produced during the war, some fears existed as to the possible effects of high temperature stripping on the mechanical properties of the castings and on their liability to distortion. In order to investigate these questions, the Sub-committee was appointed by the Technical Council on September 11, 1946, with the following terms of reference:—"To study the influence of stripping temperature on the structure and properties of pearlitic grey cast iron."

Constitution

The constitution of the Sub-committee was as follows:—Mr. M. M. Hallett (chairman), Mr. L. B. Bull, Dr. A. B. Everest, Mr. R. L. Handley, Mr. F. J. McCulloch, Mr. C. A. Payne, Mr. P. A. Russell, Mr. H. Sunderland, and Mr. G. Lambert (secretary).

In addition, Mr. P. H. Drury and Mr. F. Unsworth served on the Sub-committee under the Gardom Student Scheme and Mr. R. A. Dodd, of the Department of Industrial Metallurgy of the University of Birmingham, who is making a special study of internal stress in cast metals, was co-opted on to the Sub-committee during the later stages of its work.

The Sub-committee was originally constituted under the chairmanship of Mr. A. E. McRae Smith. Mr. McRae Smith unfortunately found it necessary to resign, owing to pressure of other work, when the Sub-committee's life was far advanced. Mr. G. W. Nicholls also served as a member for a limited period.

In order to keep the scope of the inquiry within reasonable limits, it was decided to consider only the case of castings stripped as a complete whole and cooled to room temperature in still air. No attention was given to the effects of accelerated cooling after stripping, nor to the common practice of stripping only certain parts of a given casting in order to reduce distortion or cracking. It was also assumed that the castings were not subject to mechanical damage during the stripping operation.

At an early stage in the discussions, it was recognised that the work could be divided under two fairly clear headings, *viz.*, the influence of stripping temperature on the physical properties of cast iron, and its influence upon the castings themselves, shown as distortion and cracking resulting from residual internal stress. The present Report is divided into two sections dealing with these two aspects of the problem.

*Presented at the Annual Conference of the Institute of British Foundrymen.

Survey of Available Information

As a first step, a survey of the literature was made, and it was reported that no work on this problem had been published. The discussions during the meetings of the Sub-committee did, however, indicate that there were certain general impressions within the foundry industry on the effect of stripping temperature. In order to draw on this field of experience, a questionnaire was circulated to a large number of foundries who were judged to be likely to have information, and replies were received from 15. These replies were carefully analysed, but, with one exception, it was felt that they did not provide any quantitative data on the questions under consideration. Nevertheless, there were some general conclusions which could be formed from the evidence provided. In the first place, it appeared that higher tensile strength and hardness values were obtained on castings which were stripped at a red heat, probably above the critical point. The differences reported ranged very widely from about 1 ton per sq. in. tensile strength on plain iron castings to as much as 9 tons per sq. in. as an exceptional instance on small alloy iron castings. Generally, the Brinell hardness was considered to be raised by 20 to 30 points as a result of this practice. In castings which were liable to distortion and cracking, the general practice was to leave them in the mould until they were cold, or nearly so, before stripping.

These conclusions were, of course, in line with what would be expected on theoretical grounds. Stripping the castings from a mould at a high temperature would tend to induce a measure of air-hardening. The data provided did not, however, give sufficiently exact information upon the actual temperature at which stripping was performed, or on the effect of variation of section upon the results of stripping at high temperatures.

EXPERIMENTAL WORK ON PHYSICAL PROPERTIES

In order to explore the position in a quantitative manner, it was necessary to devise some method of measuring the temperature of the castings with a sufficient degree of accuracy. There was practically no information upon the rate of cooling of various sizes of bars in sand moulds, or upon temperature gradients within castings of various sizes. It would be unduly tedious to insert thermocouples in every

Effect of Stripping Temperature

test-bar produced, and the couples would, in any case, tend to interfere with the preparation of satisfactory test-pieces.

It seemed possible that the rate of cooling of a standard size of test-bar would be sufficiently constant to enable its temperature to be estimated merely by measuring the time after casting, provided that the cooling curve had been accurately determined in advance under the same conditions. A number of experiments were, therefore, carried out on 2.1-in. diameter and $\frac{7}{8}$-in. diameter test-bars, in order to determine their cooling rates and to assess the degree of reproducibility of the various factors influencing these rates. The considerable amount of experimental work involved in these tests is not strictly relevant to the purposes of this report, but was thought to be of sufficient interest to publish, and is, therefore, dealt with separately in the Appendix. These results led to the conclusion that the temperature of 2.1-in. diameter and $\frac{7}{8}$-in. diameter test-pieces, could be determined with sufficient accuracy, say, within ± 20 deg. C. merely by measuring the time after the casting operation. It was thus possible to pour test-bars and to strip them at definite temperatures, by stripping at stated times after the casting operation.

The test-bars employed for the determination of the mechanical properties were 2.1 or $\frac{7}{8}$ in. diameter, British Standard bars, cast vertically in oil-sand moulds and top-poured through a tapered feeding head. The feeding head on the 2.1-in. diameter bars was 5.25 in. deep and tapered from the nominal 2.1 in. diameter (actually 2.2 in. diameter.) to a diameter of 4.4 in. The $\frac{7}{8}$-in. diameter bars were cast similarly with a feeding head $2\frac{1}{4}$ in. deep, tapering to $1\frac{1}{2}$ in. diameter at the top.

Mechanical Properties of 2.1-in. diameter bars

The experiments on the 2.1-in. diameter bars were made on two materials. The first was a low-silicon unalloyed iron of the type on which the determinations of cooling rate had been carried out earlier. The second was an iron alloyed with nickel, chromium and molybdenum, since it was thought that such an iron would show more strongly any effects resulting from stripping at high temperatures. The analyses of the two materials, together with details of the results, are set out in Tables I and II.

In each iron, five 2.1-in. diameter bars were cast in sand cores having a mould wall thickness of 4 in. Exactly the same set-up was employed as for the determination of the cooling curves, so as to obtain identical cooling conditions. At the appropriate intervals of time after casting, as indicated by the cooling curve, one bar was rapidly stripped from the mould and was allowed to cool by resting it across an empty moulding box, which touched only each end of the bar, so that the bar was in a horizontal position and 8 in. above a dry sand floor. The bars were screened from draughts. The stripping temperatures adopted were 950, 800, 600, 400 deg. C. and room temperature.

TABLE I.—*Results of Tests on 2.1-in. Bars of Unalloyed Cast Iron.*

Composition: T.C, 2.84; Si, 1.22; Mn, 1.00; P, 0.38; Ni, 0.25; and Cr, 0.04 per cent.

Mechanical property.	Stripping temperature, deg. C.				
	950.	800.	600.	400.	20.
Modulus of rupture, tons per sq. in.	32.0	33.0	33.2	33.6	37.6
Deflection, in.	0.16	0.18	0.23	0.23	0.25
Tensile strength, tons per sq. in.—					
Individual values	21.8 19.2	20.0 20.4	19.2 18.6	18.4 18.0	17.6 17.0
Average	20.5	20.2	18.9	18.2	17.3
Impact value, ft.-lb. (B.S. 1349)—					
Individual values	10 9 9	12 21* 18*	11 11 9	11 11 21*	10 10 11
Average	9.3	12.0	10.3	11.0	10.3
Brinell hardness (average of four across section)	278	283	242	254	250

* Multiple fracture or fracture in grips.

TABLE II.—*Results of Tests on 2.1-in. Bars of Nickel-Chromium-Molybdenum Cast Iron.*

Composition: T.C, 2.81; Si, 1.85; Mn, 1.07; P, 0.26; Ni, 1.57; Cr, 0.73; and Mo, 0.34 per cent.

Mechanical property.	Stripping temperature, deg. C.				
	950.	800.	600.	400.	20.
Modulus of rupture, tons per sq. in.	31.0	32.0	27.8	31.3	33.1
Deflection, in.	0.20	0.18	0.18	0.18	0.18
Tensile strength, tons per sq. in.—					
Individual values	19.6 15.2	19.6 17.8	20.4 17.6	20.0 17.0	19.4 18.0
Average	17.4	18.7	19.0	18.5	18.7
Impact value, ft.-lb. (B.S. 1349)—					
Individual values	8 8 25*	31 29*	25* 7 49*	8 7	7 9 32*
Average	8	8	7	7.5	8
Brinell hardness (average of four across section)	26	340	310	271	290

* Multiple fracture or fracture in grips.

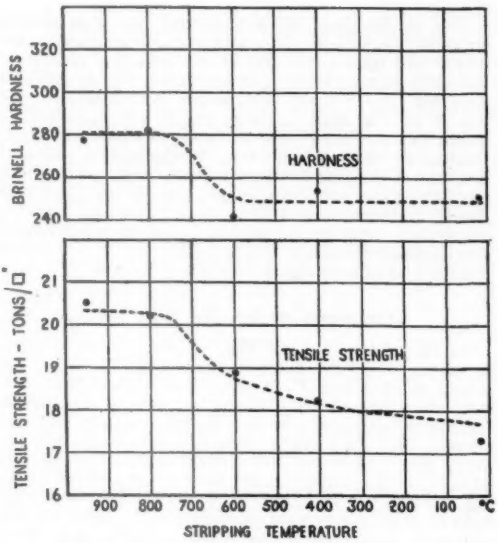


FIG. 1.—EFFECT OF TEMPERATURE OF STRIPPING ON THE MECHANICAL PROPERTIES OF 2.1-IN. DIA. BARS IN UNALLOYED CAST IRON.

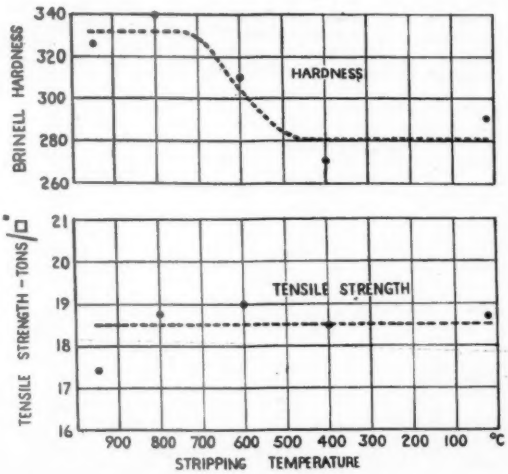


FIG. 2.—EFFECT OF TEMPERATURE OF STRIPPING ON THE PROPERTIES OF 2.1-IN. DIA. ALLOY CAST-IRON BARS.

The cooled bars were each broken in transverse on a span of 24 in. From the bottom halves of the broken transverse test-bars two tensile test-pieces with a parallel portion 0.798 in. diameter were machined. From the top halves of the bars were machined three impact test-pieces to B.S. 1349, and a slice $\frac{1}{2}$ in. thick was cut across the section for determination of Brinell hardness.

The complete results are shown in Tables I and II and certain of the average values have been plotted in Figs. 1 and 2. Considering first the unalloyed iron, a fairly steady rise in tensile strength with increasing stripping temperature is noted, though there is a tendency for the sharpest rise to come between the temperatures of 800 and 600 deg. C. A very similar curve is given by the Brinell hardness values, the rise between 800 and 600 deg. C. being more pronounced. On the alloy iron, the tensile strength values were more nearly constant and were considered to vary only within the limits of experimental error, but the hardness determinations followed the same course as on the unalloyed iron, though they were naturally at a higher level. The other determinations of transverse properties and impact values gave irregular results, which do not lead to any definite conclusions.

Mechanical Properties of $\frac{7}{8}$-in. diameter bars

A series of tests were carried out in a corresponding manner on the $\frac{7}{8}$-in. diameter bars, again following the same procedure as was used in determination of the cooling curves. These tests were confined to an unalloyed iron of a silicon content to suit the section. The results are recorded in Table III and plotted in

TABLE III.—*Results of Tests on $\frac{7}{8}$-in. Diameter Bars of Unalloyed Iron*

Composition: T.C, 3.33; Si, 2.23; Mn, 0.71; S, 0.08; and P, 0.05 per cent.

Mechanical property.	Stripping temperature, deg. C.				
	850.	700.	600.	450.	20.
Modulus of rupture, tons per sq. in. ..	32.0	31.2	31.4	29.5	29.7
Tensile strength, tons per sq. in.	17.4	16.5	15.7	15.7	15.9
Impact value, ft.-lb. (B.S. 1349) ..	17.0	15.5	16.5	15.3	12.0
Brinell hardness (average of four) ..	223	204	192	192	188

Fig. 3. On these bars nearly all the mechanical properties showed a definite change with varying stripping temperature. In the case of tensile strength and Brinell hardness, it is interesting to note that the major rise in properties again comes between 800 and 600 deg. C. It is clear that when cast iron is cooled in air from a temperature above the critical transformation point, there is a tendency for air-hardening to set in, with consequent increase in hardness and tensile strength, sometimes accompanied by increase in transverse strength and impact value.

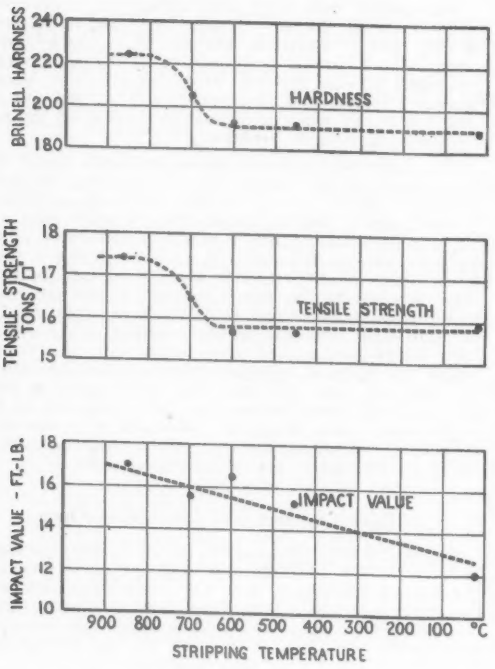


FIG. 3.—EFFECT OF TEMPERATURE OF STRIPPING ON ¾-IN. DIA. UNALLOYED CAST-IRON BARS.

One of the firms which answered the questionnaire supplied an interesting series of confirmatory tests. These tests were qualitative in the sense that the actual stripping temperature was not determined, but the apparent temperature was noted by observing the colour of the bars. These values are recorded in Table IV, and confirm in all respects the conclusions reached by the Sub-committee. Stripping at a temperature above the transformation point tends to result in strength values (modulus of rupture in this case) and Brinell hardness higher than those obtained on bars allowed to cool in the mould to room temperature. The deflection values generally moved in the same direction as the modulus of rupture figures.

Experiments on Smaller Test Pieces

As may be seen from Fig. 4, the rate of cooling in air of a 2.1-in. diameter bar removed from the mould at 900 deg. C. is very much faster than the rate of cooling of an identical bar left in the mould for the whole time. As the diameter of the bar decreases, the two cooling rates will obviously tend to move closer together, and it seemed probable to the Sub-committee that at some section the rate of cooling of the bar cast into a sand mould would be quicker than the rate of cooling of the same bar in still air. It seemed worth while to carry out some experimental work on this point, since the conclusions from the results on the Sub-committee's work on 2.1-in. and ¾-in. diameter bars would be reversed at such a section. Cooling curves were, therefore, carried out on a 0.3-in. diameter bar, both when allowed to cool in the mould to room temperature, and after stripping from a temperature of approximately 900 deg. C. Owing to the high rate of cooling, the actual time of stripping extended over a considerable tem-

TABLE IV.—*Further Tests on ¾-in. Diameter Bars.*

Mechanical property.	Stripping temperature.		
	Bright red.	Dull red/black.	Black.
Composition : T.C, 3.25 ; Si, 2.27 ; Mn, 0·73 ; and P, 0.19 per cent.			
Modulus of rupture, tons per sq. in.—			
Individual values	36.1 33.5	30.2 31.5	29.8 30.0
Average	34.8	30.9	29.9
Deflection, in.—			
Individual values	0.145 0.135	0.140 0.130	0.130 0.120
Average	0.140	0.135	0.125
Brinell hardness (average of two)	245	229	226
Composition : T.C, 3.27 ; Si, 2.05 ; Mn, 0.83 ; P, 0.19 ; and Cr, 0.27 per cent.			
Modulus of rupture, tons per sq. in.—			
Individual values	36.8 38.0	34.0 34.5	33.0 37.0
Average	37.4	34.3	35.0
Deflection, in.—			
Individual values	0.150 0.150	0.135 0.145	0.130 0.150
Average	0.150	0.140	0.140
Brinell hardness (average of two)	257	240	241

No difference in machinability was noted in any of the bars when machined at 125 ft. per minute with a cut of ⅛ in. depth and a feed of 0.008 in.

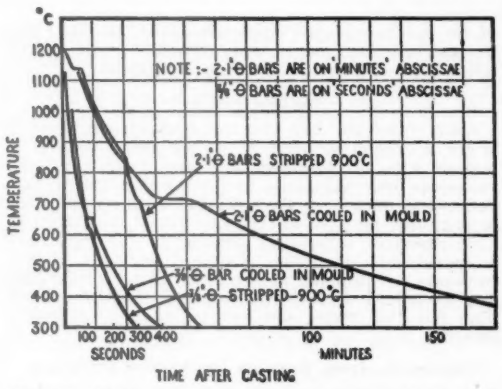


FIG. 4.—COOLING CURVES FOR SAND-CAST GREY-IRON BARS.

perature range, actually 975 to 750 deg. C., but at 750 deg. C. the bar was still above its critical point, so that the major objects of the experiment were achieved. It will be seen from Fig. 4 that, even with this very small test-bar, the rate of cooling in air is still a little faster than the rate of cooling in the sand mould. No further cooling curves were determined, since the Sub-committee felt that the section at which the cooling rates might reverse was clearly so small that the question was only of academic interest, on account of the high cooling rates with either type of cooling medium.

Some confirmatory hardness experiments were performed on 0.6-in. and 0.3-in. diameter bars stripped at about 900 deg. C. and at room temperature. Hardness tests were chosen for this work partly because of their convenience, and partly because the earlier work had shown that hardness of the various properties studied reacted most consistently and definitely to changes in stripping temperature. The results are shown below:—

Diameter of test-bar.	Type of test.	Hardness after stripping at	
		About 900 deg. C.	Room temperature.
0.6 in.	2-mm.-ball, 120 kg...	223	217
0.3 in.	Vickers diamond, 50 kg. load.	270	270

In each case the iron was unalloyed, low phosphorus material of a silicon content to suit the section, *i.e.*, 2.25 to 2.6 per cent. These show that, at the high cooling rates inherent in the smaller sections, the effect of stripping temperature can be neglected.

A further series of Brinell hardness tests was carried out for the Sub-committee, these tests being qualitative so far as temperature measurement was concerned. A number of blocks 3 in. square and ranging in thickness from ¼ in. to 1¼ in., were cast and stripped after a number of intervals corresponding roughly to the temperatures indicated by the colour observations shown in Table V. The composition of the iron is quoted with the Table. The high silicon content was utilised to ensure that the ¼-in. sections were grey.

The Brinell hardness tests were made at the centre of each block on the top and the bottom face, using a 3,000-kg. load and a 10-mm. ball. Some further tests were made on two of the blocks, these being nearer the edges (¼ in. from the edge on the top face only) and the figures are recorded in Table VI.

Considered as a whole, both of these sets of results indicate that stripping of thick castings at a high temperature tends to give higher hardness values than cooling in the mould down to room temperature. Thin sections do not show this tendency so markedly, since

TABLE V.—*Brinell Hardness on Centre of Plate Castings.*

Composition: T.C, 3.45; Si, 2.46; S, 0.081; P, 0.564; Mn, 0.56 per cent.; and Ni, trace.

Casting temp., deg. C. (optical pyrometer).	Stripping time.	Colour of thick section when stripped.	Face (top or bottom).	Brinell hardness number. Section thickness.					
				¼ in.	½ in.	¾ in.	¾ in.	1 in.	1¼ in.
1,290	1 min.	Not set	T	235	223	235	217	207	201
			B	248	223	235	212	212	207
1,290	2 mins.	Bright red ..	T	255	217	187	207	207	197
			B	255	217	201	217	217	188
1,285	4 mins.	↓	T	255	235	212	192	192	187
			B	255	235	217	212	207	197
1,280	10 mins.	↓	T	241	223	235	235	212	201
			B	235	223	223	217	223	212
1,275	20 mins.	Dull red ..	T	241	212	217	197	201	187
			B	241	217	217	201	207	207
1,270	16 hrs.	Black	T	241	229	223	183	201	187
			B	241	229	217	201	207	192

Effect of Stripping Temperature

the cooling rates are fairly high in either case. Some of the individual determinations on these cast iron plates show results which are not in line with these general conclusions, but, when allowance is made for normal variation of hardness in grey cast iron, it is felt that the results confirm the main conclusions.

Machinability

The only case in which a definite report was made to the Sub-committee with regard to machinability is referred to at the bottom of Table IV in the additional tests on $\frac{7}{8}$-in. diameter bars. Here no difference in machinability was noted between any of the bars stripped over a range of temperatures. Although no report was requested from the machine shops concerned, no comment was made on change in machinability on either the 2.1-in. bars or the remaining $\frac{7}{8}$-in. bars. This rather indefinite evidence suggests that marked changes in machinability need not be expected as a result of stripping at a high temperature, but should certainly not be regarded as proof that changes will never be noted in any cases. Machinability is very sensitive to minor changes in structure and hardness, and it is quite possible that at critical sections and compositions a decrease in machinability might be experienced after stripping at high temperature.

Microstructure

The most interesting evidence under this heading came from the series of small plate specimens of varying thickness, details of which are given in Table V. Because of the relatively high silicon content, these castings were sensitive to changes in cooling rate, and it was found that, while the $\frac{1}{4}$-in. sections stripped from a high temperature showed a structure consisting almost entirely of very fine pearlite, heavier sections, such as those $\frac{1}{2}$ in. thick, cooled in the mould to room temperature, showed approximately 10 per cent. of ferrite and the pearlite was distinctly coarser. This is in line with the hardness values, and, as would be expected from them, none of the specimens showed any signs of martensite. All the 2.1-in. diameter and $\frac{7}{8}$-in. diameter bars examined during determination of the mechanical properties were fully pearlitic, and no marked changes in microstructure were noted following variations in stripping temperature.

Surface Finish

Apart from the fact that test-bars (particularly of larger diameter) stripped at a red heat, showed a pinkish film of adhering fine sand instead of the customary blue skin, due to the burning out of carbonaceous matter in the adhering sand at the high temperature, no very marked changes in surface finish were reported. One firm considered that there was a possibility that the slightly increased surface oxidation on stripping at the high temperature might lead to somewhat greater adherence of the surface sand film, but the matter was not regarded as definitely proved.

Conclusions from Tests on Mechanical Properties

(1) In unalloyed grey cast iron, the tensile strength and Brinell hardness tend to increase with increase in stripping temperature.

(2) In a few experiments on alloyed iron, the Brinell hardness (generally at a higher level than in the unalloyed iron) similarly tended to increase with increasing stripping temperature, but in these cases no comparable trend was observed in the tensile strength.

(3) Change in tensile strength and Brinell hardness is most marked on stripping near the critical point, indicating that the change in properties is due to slight air-hardening.

(4) Transverse properties and impact values tend to show an irregular response to change in stripping temperature.

(5) The mild air-hardening effect occurs at section thicknesses ranging from $\frac{1}{2}$ to 2.1 in. (as studied so far), but owing to the similarity in the cooling rates of thinner sections in the mould and in still air, the difference is not so marked.

DISTORTION OF CASTINGS

The determination of the relationship between stripping temperature and mechanical properties was fairly straightforward, but the problems of distortion and cracking in castings, and the effect of stripping tem-

TABLE VI.—*Brinell Hardness Near Edge of Plate Castings.*

Stripping time.	Position.	Brinell hardness number. Section thickness.					
		$\frac{1}{4}$ in.	$\frac{1}{2}$ in.	$\frac{3}{4}$ in.	$\frac{7}{8}$ in.	1 in.	$1\frac{1}{2}$ in.
1 min. after casting	1	217	*	*	*	*	*
	2	241	217	229	217	217	207
	3	(Specimen	229	235	217	212	207
	4	broke)	229	223	223	217	201
4 mins. after casting	1	217	212	212	187	192	179
	2	241	217	212	192	197	187
	3	255	229	217	192	201	187
	4	255	229	217	197	201	197

* Hardness reading nearest to runner edge not possible owing to casting not having solidified at moment of stripping.

perature on them, are much more complex, so that the results obtained on any one casting are often of limited application. There has been some confusion of thought on the subject in the past, and it may be advisable to consider briefly the causes of distortion before describing the Sub-committee's work.

Causes of Distortion

Distortion is always due to internal stresses in a casting, and these stresses generally arise from one of two main causes. The first is resistance to contraction, due to the inability of the mould material to be crushed by the shrinking casting. A typical case is that of a straight pipe provided with wide flanges at each end. As the casting contracts lengthwise during cooling, the sand between the two flanges tends to prevent this contraction and leads to hot-tearing. It is obvious that in this case the sand mould needs to be broken away from the casting as soon as possible after solidification, so as to allow free contraction. Factors such as hard ramming tend to exaggerate the trouble.

The other major factor arises from the difference in the speed of cooling of heavy and light sections. If one considers two limbs of a casting, one thick and one thin, connected at their ends, the thin section will have cooled down to a comparatively low temperature at a time when the thick section is only just solid. The thick section then contracts by normal thermal contraction, but this contraction is resisted by the thinner section, which has already almost completed its normal contraction. The result is to impose a tensional stress on the heavy section, and a compressive stress on the lighter section.

Depending on the relative proportions of the two sections, the heavy section may crack or the lighter section may bend and even break. The important point is that it is the difference in temperature resulting from the difference in cooling rates between the two sections which determines the stress developed. Each limb has to contract finally by the same amount, but the difference in temperature controls the proportion of the contraction in the heavier section, which is hindered by the already-rigid lighter section. Similar stresses arise in a beam of more complex shape, such as a tee section with a heavy base. In this case the thinner projecting rib cools appreciably faster than the heavier base, leading to distortion or curvature of the beam.

The effect of stripping at a high temperature will generally be to decrease the difference in temperature developed between sections of varying thickness, because the rate of cooling of a section in free air is very much faster at a high temperature than it is at a low temperature, thus giving the heavy section an opportunity to " catch up " to some extent on the cooler, lighter section. It should at this point be emphasised that the Sub-committee has regarded its terms of reference as covering only complete stripping of a casting from the mould, and not to include the well-known and obviously advantageous foundry practice, that of stripping a part of the casting, whilst leaving other sections embedded in the sand.

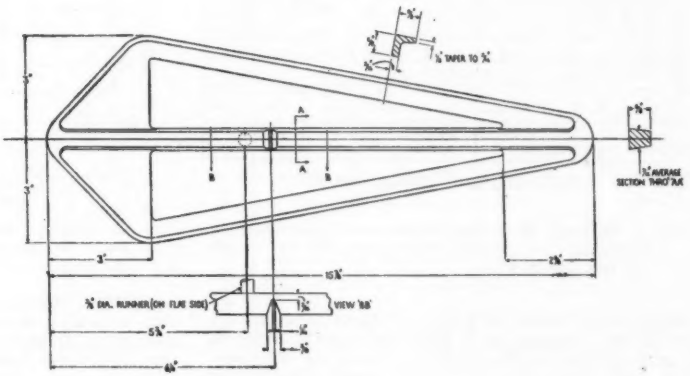


FIG. 5.—GRID CASTING FOR TESTS ON INTERNAL STRESS.

Effect of Design

It must also be borne in mind, that the thermal condition of the surrounding sand mould has to be considered as well as that of the casting. As cooling in the mould progresses, the sand itself becomes increasingly heated, particularly by conduction from the heavier sections of the casting. In compact castings with thick and thin sections closely spaced, the heating of the sand exercises a very powerful effect in equalising the temperature throughout the casting and so reducing the thermal stresses, and it is this factor which explains the experience of many foundries that distortion is less if the casting is allowed to cool in the mould down to room temperature.

Effect of Stripping Temperature

It is clear from the above that the effect of stripping temperature upon distortion is not a constant factor, but will be determined by the design of each casting, and will be peculiar to that particular casting, since the ratio of the varying sections, and their disposition to each other, will determine whether stripping at a high temperature has a beneficial effect in reducing distortion by equalising the rates of cooling of different limbs, or whether greater equalisation will result from slow-cooling in the mould.

In general, it may be said that a casting with widely spaced limbs is likely to show decreased distortion on stripping at a high temperature, whereas, a casting in which the various sections are in reasonably close proximity, will attain greater equalisation of temperature, and hence, suffer less distortion by cooling down to room temperature in the mould.

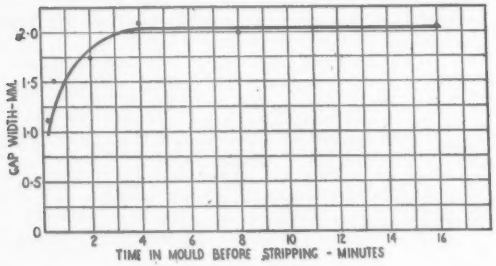


FIG. 6.—EFFECT OF INTERVAL BETWEEN CASTING AND STRIPPING ON STRAIN PRODUCED IN THE GRID CASTING (SERIES 1).

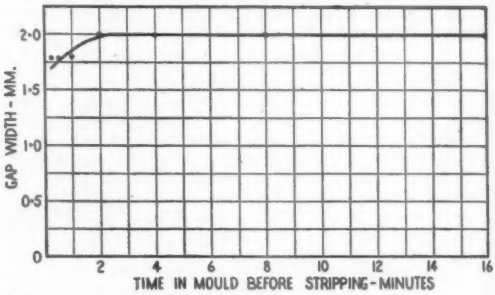


FIG. 7.—EFFECT OF INTERVAL BETWEEN CASTING AND STRIPPING ON STRAIN PRODUCED IN THE GRID CASTING (SERIES 2).

Experimental Work on Distortion

With these considerations in mind, the experimental work of the Sub-committee on the distortion of castings has centred around three designs of casting:—

(*a*) A casting consisting essentially of a square bar, on one side of which projects a thin rib. From each end of the bar on the rib side projects at right-angles a side member of the same thickness as the rib, the end of each side member being turned inward in an opposing direction to form a gap, the dimensions of which measure the tendency of the bar to bend. It was found that results on this type of casting were complicated by movement in a plane at right-angles to the plane of gap movement, and that the results were thereby rendered too irregular to be useful.

(*b*) A casting consisting of two parallel members, one of heavier section than the other, the ends being connected by cross members, which were projected for a considerable distance to form reference pointers. Some of the results on this casting have been more promising, but the work has not progressed sufficiently far to justify reporting at this stage.

(*c*) A three-limbed grid casting illustrated in Fig. 5 This consists essentially of two relatively light outer limbs which formed part of a quick setting frame rigidly holding the one relatively heavy central limb. It was expected that the difference in rate of cooling would lead to the development of tensional stresses in the centre limb. This expectation was realised and two methods of measuring change in internal stress were studied. The first involved measuring the width of the gap caused when the centre limb cracked, while the other utilised strain gauges. In studying the first method, it was found essential to cause the crack to occur at a definite spot in the centre limb, since, if this condition was not imposed, the side members themselves frequently broke outwards as a result of the compressive stresses before the centre limb cracked under tension. The location of the crack was ensured by cutting a deep notch at one point of the centre limb, as indicated in Fig. 5.

With this arrangement a series of castings was made in a soft grey iron of high silicon and phosphorus contents. The castings were knocked out from the mould at intervals of quarter, half, one, two, four, eight and sixteen minutes, and 18 hours after casting. All the castings cracked at the slot. They were sand blasted, and after very light filing to remove surface irregularities, the width of the crack was measured, using a scale in the eyepiece of a microscope. This series was repeated a second time in the same iron and once more using a stronger iron of lower silicon and phosphorus contents.

The results are set out in Table VII and are plotted in Figs. 6, 7 and 8. Although there is some spread in the individual values obtained, all the curves show an increase in gap movement with increasing time in the mould before stripping, thus suggesting, that, in this casting, stripping at a high temperature tended to reduce the temperature difference between the centre limb and the outside limbs, and thus to reduce the internal stresses. Table VII also includes the thickness of the

TABLE VII.—*Distortion on Three-limbed Grid Casting.*

Time left in mould before stripping.	Thickness of centre limb, in.	Approximate average width of gap, mm.
First Series (M Iron)—		
½ min.	0.685	1.12
¾ ,,	0.655	1.52
1 ,,	0.653	1.50
2 ,,	0.680	1.75
4 ,,	0.685	2.10
8 ,,	0.668	2.00
16 ,,	0.680	2.05
18 hours	0.670	2.00
Second Series (M Iron)—		
½ min.	0.660	1.78
¾ ,,	0.684	1.78
1 ,,	0.660	1.80
2 ,,	0.670	2.00
4 ,,	0.663	2.00
8 ,,	0.664	2.00
16 ,,	0.676	2.00
18 hours	0.668	2.00
Third Series (H Iron)—		
½ min.	0.675	1.38
¾ ,,	0.652	1.25
1 ,,	0.685	1.50
2 ,,	0.665	1.50
4 ,,	0.675	1.50
8 ,,	0.670	1.93
16 ,,	0.668	1.98
18 hours	0.667	2.00

M Iron = T.C, 3.2 to 3.4; Si, 2.8 to 3.0; Mn, 0.8 to 1.0; and P, 1.0 to 1.2 per cent.
H Iron = TC, 3.2 to 3.4; Si, 2.1 to 2.3; Mn, 0.8 to 1.0; and P' 0.3 to 0.4 per cent.

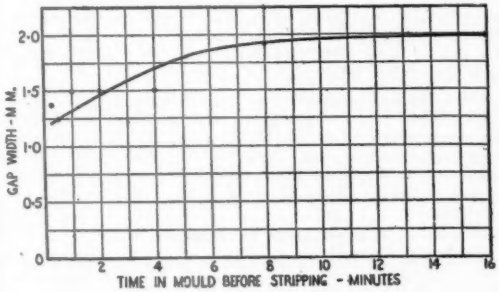


FIG. 8.—EFFECT OF INTERVAL BETWEEN CASTING AND STRIPPING ON STRAIN PRODUCED IN THE GRID CASTING (SERIES 3).

centre limb, since it was felt that the slight variations should be recorded.

Using the same casting, but without the locating notch in the centre limb, *i.e.*, leaving it as a parallel member, though of slightly reduced thickness to lower the stress in the outer limbs, another series of castings was prepared and stripped at a range of temperatures. Electric resistance strain gauges were attached to the centre limb of the cold castings and the limb was sawn through to relieve the stresses. The change in resistance of the strain gauges enabled the tensional stresses in the centre limb to be determined on the assumption that the modulus of elasticity of the iron was 14×10^6 lb. per square inch. It may also be noted that the tensile strength of the iron was about 12 tons per square inch. The tensile stresses determined by this method are shown as follows:—

Stripping time.	Tensile stress in centre member, tons per sq. in.
½ minute	1.44
1 minute	3.47
2 minutes	4.16
4 minutes	4.50
16 minutes	5.60

The results are plotted in Fig. 9, and show a very similar course to the curves of Figs. 6, 7 and 8, leading to similar conclusions. Further work is being undertaken in an effort to study the effect of heating up the surrounding sand experienced in large castings, as discussed above.

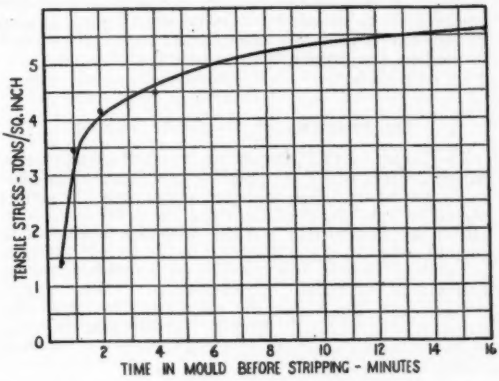


FIG. 9.—EFFECT OF INTERVAL BETWEEN CASTING AND STRIPPING ON THE INTERNAL STRESS IN THE GRID CASTING.

Conclusions from Tests on Distortion

1. Results obtained on any one type of casting are limited in their application to that type, and the conclusions may be reversed on other types of casting.
2. In light castings with widely spaced limbs differing in cross section, there is a definite decrease in distortion and in internal stress by stripping at a high temperature, instead of allowing the casting to cool in the mould to room temperature.

(*To be continued.*)

Di-electric Core Drying

The shortage of linseed oil and similar binders, which have hitherto been used almost universally in core-making, has led foundrymen and metallurgists to seek alternative materials. Of the many types of compounds tried, those which have shown the most promise are the synthetic resins, particularly phenol-formaldehyde and urea-formaldehyde. This is due to two principal factors, namely:—(1) They are excellent binders producing cores possessing good foundry properties, and (2) they have a much shorter curing cycle than linseed oil and allied drying oils. Consequently, they may be dried by the di-electric-loss method of heating, with the great practical advantage of saving in time and cost.

Di-electric or radio-frequency heating are the names given to a new method of heating electrically non-conductor materials. Its development and adoption as a method of applying heat has led to a great saving of time and cost in many industries; for example, the preheating of moulds in the plastics industry, the manufacture of plywood and furniture, the curing of rubber and similar materials of low thermal conductivity. In many cases, drying time has been reduced from hours to minutes and even seconds. By the adoption of this method of heating the foundry industry also has the opportunity to benefit by showing similar great savings in time and cost of core manufacture, especially when it is used in conjunction with the rapid-curing synthetic-resin core binders.

The Principles of Di-electric Heating

Di-electric heating depends on a high-frequency alternating current which is applied to the plates of an electrical condenser. The material to be heated is simply placed between the two plates and subjected to rapidly-alternating electrostatic stresses, with the result that at each alternation of the current a small quantity of heat is produced within the material in proportion to the quantity of electrical friction induced. Consequently, within limits, the higher the alternating frequency the more rapid is the rate of heating. In addition, by virtue of the method, the temperature rise throughout the mass of the material is uniform.

Method of Operation

It has already been implied that radio-frequency di-electric heating is simple in operation; it can be briefly described as follows:—The sand core is placed between two condenser plates which act as electrodes. The normal mains electricity supply is transformed by means of a specially-designed apparatus to high-frequency alternating current which is fed to the electrodes. The heat, which is created uniformly within the core, rapidly completes the curing operation.

Experimental work has been carried out in a fully mechanised foundry using synthetic core binders in conjunction with normal sands, employing a Ferranti-Wild-Barfield di-electric heating set, type 10 ADP., of electrode size 19 in. by 22 in. for drying. Various sizes of cores were treated, varying in weight from ¼ lb. to 27 lb., and the drying times of the cores baked by the di-electric method were compared with those cured by convection heating.

Core.	Core weight.	Heating time in minutes. Di-electric.	Core oven.
A	¼ lb.	2.5	90
B	7 lb.	4.0	105
C	27 lb.	10.0	240

All cores which were heated by the di-electric method were found to be dried right through to the centre. In comparative tests made between di-electrically-heated and oven-baked cores, the former were substantially higher in dry strength than the latter. Furthermore, strength and hardness were more uniform throughout the mass of those electrically dried.

Advantages of Radio-frequency-dried Synthetic-resin Cores

The use of synthetic-resin core binders in conjunction with the rapid curing technique of high-frequency heating offers the following advantages:—(1) Speed of baking; (2) reduction in number of core carriers and driers necessary; (3) reduction in the handling of cores and labour required, particularly with a properly-adjusted di-electric heating unit as part of a conveyorised system; (4) good casting finish; (5) good collapsibility and knock-out properties; (6) increased dry strength; (7) simplified production line, resulting from absence of delays between moulding and casting; (8) saving of space; (9) no waste heat; (10) less gassing than with linseed-oil cores; (11) an extremely wide margin of safety due to self-adjustment of the power factor as drying proceeds; (12) reduction in the use of core wires and irons, and (13) core-blowing technique is not affected.

Once the sand mixture has been established, no difficulty should be experienced in drying cores by the di-electric method. The low-temperature-curing resins are very responsive to heat and, together with silica, the primary constituent of sand, lend themselves admirably to this method of heating, both having high di-electric constants.

Production Equipment

Production equipment may be of either the batch or continuous type, according to the quantity of cores required to be handled.

(1) Batch-type equipment provides for manual handling throughout, the power being switched on and off as required. By this method the di-electric-heating equipment is only used from one-third to one-half of its capacity.

(2) Continuous-type equipment is much more efficient from both the drying and the handling points of view. The heating equipment is incorporated as part of a conveyorised handling system, the cores being dried as they pass through the condenser plates. In this way, the best results from radio-frequency-dried synthetic-resin-bonded cores may be obtained.

Factors Controlling the Hot-tearing of Aluminium Casting Alloys*

By D. C. G. LEES, M.A., A.I.M.†

Summary

Exhaustive studies have been made during the past few years of the factors controlling the incidence of hot-tearing in aluminium alloys. Super-purity aluminium and the eutectic alloys do not show tearing even when cast under severe restraint; initial additions of alloying elements, such as silicon or copper, introduce tearing which increases and reaches a maximum at about the limit of solid solubility under the conditions of freezing, subsequently decreasing and falling to zero. Cracking at temperatures below the solidus is a function of brittleness in the solid state and is unusual in aluminium alloys in normal practice. Hot-tearing has been shown to take place above the solidus.

The factor principally controlling the severity of tearing is the extent of the brittle range of temperature from the point at which the alloy first becomes coherent to the effective solidus under the relevant conditions. In this range, where the primary dendrites have grown sufficiently to interlock with each other and in which there remains a certain amount of residual liquid, the alloy is brittle and liable to crack under the influence of stresses set up by the restraint of free contraction or by premature handling. On passing the effective solidus, the alloy gains a measure of ductility.

Under favourable conditions, cracking may be averted by the process of accommodation, *i.e.*, slight re-arrangement of the grains before freezing is complete and, further, by the flow into incipient cracks of eutectic liquid derived from portions of the casting in which freezing is less advanced. Thus, freedom from hot-tearing may be regarded as being a function of the extent of the brittle range (which is somewhat similar to, but not identical with, the freezing range) or of the proportion of eutectic present—both constitutional factors. Further, any factors influencing the distribution of residual liquid may affect the incidence of hot-tearing. Among these must be mentioned grain size and gas content. Grain refinement, which reduces the severity of tearing, may be operative either by changing the distribution of the eutectic liquid or, alternatively, by easing the process of accommodation. Dissolved gas released during freezing may also reduce the severity of tearing in alloys not greatly prone to the defect by displacing eutectic liquid from the interstices between the primary dentrites into the intergranular space, thus facilitating accommodation.

* Presented at the 46th Annual Meeting of the Institute of British Foundrymen, at Cheltenham.

†Metallurgist, The Aluminium Development Association.

‡ References to all the Papers mentioned, with a summary of each, are given in Appendix II. The experimental methods used are described in Appendix I.

Introduction

During the past thirty years great advances mainly based on the results of scientific investigation have been made in aluminium-alloy founding. First came the realisation of the importance of dissolved hydrogen as a factor controlling the soundness of castings; this was followed by the discovery of methods for efficient degasification and the control of melting conditions so as to avoid gas absorption. In more recent years, attention has been turned to the casting characteristics of the various foundry alloys; that is to say, the extent to which shrinkage and gas unsoundness may impair mechanical properties and pressure tightness, the ease with which the alloys run in the mould and, finally, the incidence of cracks and tears in the castings. Of these properties, the last mentioned has received the most careful and extended study; this is probably due to the obvious importance of the property not only in casting, but also in welding and in forging and other forms of hot-working.

In this country, research on the factors controlling the incidence of hot-tearing in aluminium alloys has been mainly conducted in two laboratories. For the British Non-Ferrous Metals Research Association, the present Author carried out, between 1940 and 1944, an investigation of the casting properties of aluminium foundry alloys, and part of this work consisted in an assessment of their hot-tearing properties. The work originated in the wartime need to develop a ductile casting alloy from the scrap which was then available. At an early stage it was realised that many of the low-copper alloys which gave the desired tensile properties were not suitable for casting purposes particularly because of their proneness to cracking and accordingly, attention was directed to the study of the factors controlling the incidence of these defects. The part of the work dealing with hot-tearing was published in two papers (1946, 1947). The second group of investigations (made first for the Wrought Light Alloys Association and later for the Aluminium Development Association) began at the University of Birmingham in 1944 under Dr. A. R. E. Singer and is still continuing under Dr. W. I. Pumphrey. This work, which has been concerned with cracks in welds as well as in castings, has been reported in nine Papers,‡ and is later referred to as the Birmingham work.

These two groups of investigations were conducted by somewhat different methods and differed slightly in their emphasis. Thus, the present Author used one test in sand moulds and a second in permanent moulds, while the Birmingham workers used both a ring-casting test (made in dies) and a restrained-weld

Hot-tearing of Aluminium Alloys

cracking test, supported by studies on the mechanical properties of the alloys at temperatures above and below the solidus. Further, the B.N.F.M.R.A. work was mainly concerned with casting and only incidentally with welding, so that the alloys studied tended either to be comparatively rich in alloying constituents or to contain significant amounts of several elements; the Birmingham work, on the other hand, tended to be concerned with welding rather than casting and has concentrated particularly on the regions of low alloying content in binary systems. Nevertheless, in spite of these differences of approach, there is satisfactory agreement between the two groups and the purpose of this Paper is to present in simple terms the modern view of solidification, the formation of tearing and the means of avoiding it, which has emerged from the work.

The Process of Freezing in Solid-solution Alloys

It has long been realised that the tears or cracks occasionally found in castings are largely due to the restraint of free contraction and that the various foundry alloys differ significantly in their liability to the defect. An understanding of the mechanism of solidification suggested by the recent work on hot-tearing is best obtained by considering the mode of freezing of a solid-solution alloy. Pure metals and eutectics which freeze at a single temperature do not show tearing.

When a melt of a solid-solution alloy cools, solidification begins when the temperature at some point reaches the liquidus temperature.* Primary dendrites then form and on further cooling these grow at the expense of that portion of the alloy which remains liquid. In the earlier stages, the proportion of solid is small and the dendrites which have grown from points dispersed throughout the bulk of the melt are not in contact with each other (see Fig. 1 (*a*)). Such a mass, composed of much liquid with a little solid, possesses very little coherence and the contraction which is at all stages occurring can be accommodated without difficulty. With progressive fall in the temperature, the situation changes. The primary dendrites grow with branching arms and approach more and more closely to each other, so that the movement of parts of the mass relative to others becomes more difficult. Finally, the dendrites interlock and form a coherent mass (see Fig. 1 (b)); it is now that there is danger of tearing. Although the mass is coherent, such strength as it possesses is due entirely to the solid network, which is, of course, weakened by the residual liquid held between the arms of the dendrites. This is a brittle condition and if stress is applied—either by the restraint of free contraction or because of premature handling of the casting—fracture takes place with very little elongation at a stress lower than that which corresponds to the strength of the primary components themselves (see Fig. 1 (c)). With further fall in the temperature, the residual liquid freezes progressively until the process is complete at the solidus temperature. The alloy then attains its full ductility proper to the temperature.

Temperature of Formation of Hot Tears

This account of the mode of freezing shows that tearing is more likely to take place, if at all, at temperatures within the freezing range and the truth of this conclusion has been verified by experiment. Thus in part of the Author's work the contraction of bars poured in sand moulds was restrained and the restraint was released at varying times after pouring.

* A certain amount of undercooling may, of course, take place, but this effect is probably of little direct significance to the present discussion.

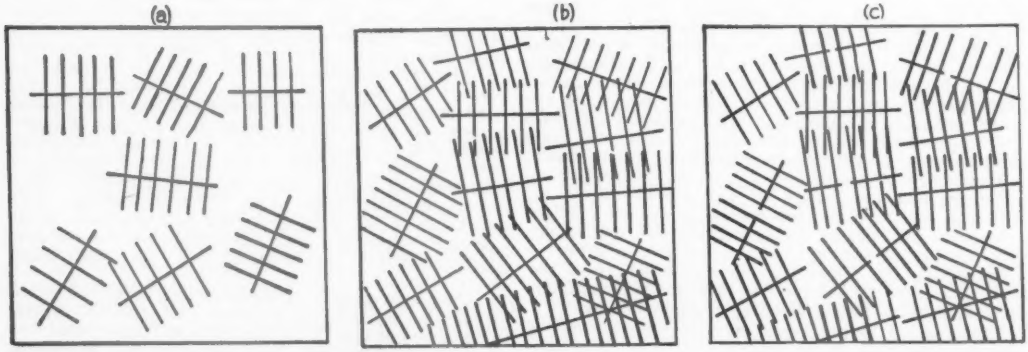


FIG. 1.—SUCCESSIVE STAGES IN THE FREEZING OF A SOLID SOLUTION ALLOY, WITH INCIPIENT HOT-TEARING FORMATION IN (*c*).

It was found that relaxation after passing the solidus did not affect the results, whilst relaxation before freezing was complete obviated tearing in alloys prone to the defect. It will later be shown how tears, initially formed in the primary network, may, under favourable conditions, be repaired before solidification is completed, but the next stage in the argument is to indicate certain factors which may now be seen to control the likelihood of tearing. Discussion will at first be limited to alloys containing different proportions of the same alloying constituent, as typified by the aluminium-silicon range.

The liquidus-solidus range is clearly dangerous, and it may be surmised that the greater the contraction undergone by the alloy on passing through it, the greater will be the probability of a tear occurring. The actual contraction occurring within this range of temperature is made up of three parts:—

(1) There is a certain shrinkage on passing from the liquid state to the solid; (2) the residual liquid contracts as the temperature falls, and (3) the primary crystals undergo solid contraction as the temperature falls.

Of these three factors, the last is the most important, since the other two will generally be compensated by the flow of liquid from other parts of the casting or from runners and risers. This solid contraction on passing through the freezing range is related to the coefficient of linear expansion of the alloy and to the length of the range.

The Effect of Alloy Composition on Hot-tearing Tendency

Since the coefficient of linear expansion varies by only a small amount with composition within a given series of binary alloys, it follows that the principal factor determining the probability of a tear occurring above the solidus, *i.e.*, a hot-tear, is the length of the freezing range. This prediction is in accordance with the experimental results obtained both by the Author and by the Birmingham workers. An example of the type of result obtained in the latter work is shown in Fig. 2 (*a*), which gives results for the aluminium-silicon series of alloys. The alloys studied were of commercial purity with an iron content of 0.20 to 0.29 per cent., while the silicon content ranged from zero to 11.83 per cent. As in the rest of the Birmingham work, the tendency to hot-tearing was indicated by the total length of cracks formed in a simple ring casting whose free contraction was restrained by an iron core. The graph indicates that there is no cracking for superpurity aluminium, while small additions of silicon (up to about 0.66 per cent.) increased the severity of cracking. Subsequent additions then caused a sharp fall in the severity of cracking until, with about 2 per cent. silicon, no cracks were found. Similar effects were found in tests on restrained welds (see Fig. 2 (*b*)). In the B.N.F.M.R.A. work, the Author obtained closely similar results, although no alloys with silicon contents less than 0.75 per cent. were studied, so that the maximum in the curve at about 0.7 per cent. was not observed. Nevertheless, the agreement between the two investigations is striking, and it is clear that the tendency towards hot-tearing closely follows the length of the freezing range, as shown from the equilibrium diagram of the binary aluminium-silicon alloys, which is also plotted in Fig. 2. In actual fact, of course, the cast alloys are not in a state of equilibrium, the

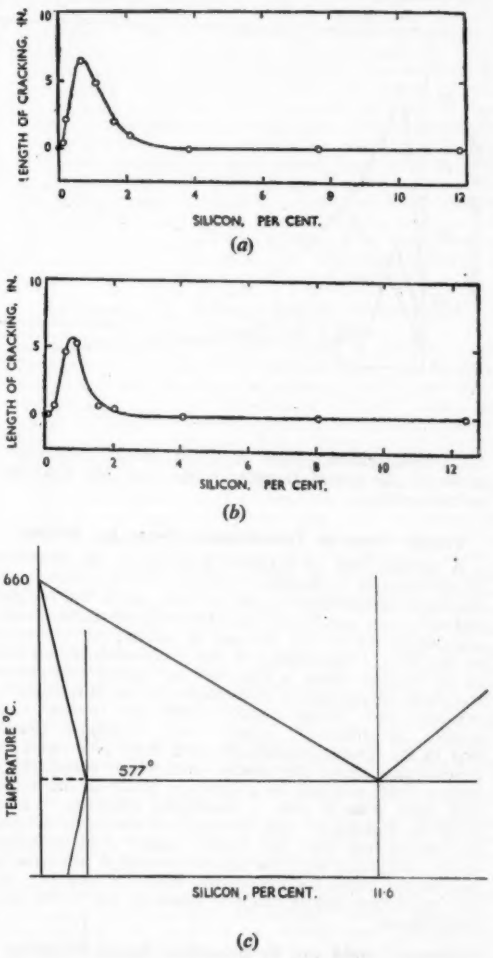


FIG. 2.—THE CRACKING IN (*a*) RING CASTINGS, AND (*b*) RESTRAINED WELDS IN THE ALUMINIUM-SILICON BINARY ALLOYS, WITH (*c*) THE EQUILIBRIUM DIAGRAM FOR THE AL-SI SERIES.

limit of silicon solubility in the as-cast alloys being lower than the equilibrium value. Consequently, the maximum freezing range under the conditions of casting occurs at a somewhat lower silicon content; indeed, this consideration gives an even closer correlation between the actual freezing range and the tendency to hot-tearing.

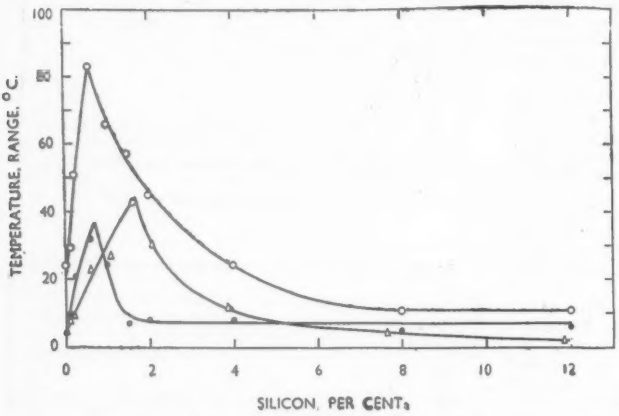


FIG. 3.—BRITTLE TEMPERATURE RANGE IN ALUMINIUM-SILICON ALLOYS.

Tensile Tests at Temperatures Near the Solidus

A further type of evidence bearing on the problem of hot-tearing is derived from mechanical tests conducted at temperatures close to and above the solidus preferably on specimens cast immediately beforehand, and which are in the process of cooling at the time of the test. Experiments of this type were carried out by the Author using a bend test on freshly cast pieces and (with much greater refinement) by the Birmingham workers who made tensile tests on freshly cast tensile specimens. Singer and Cottrell found that in the aluminium-silicon series there is a range of temperature above the solidus over which some alloys have a finite strength or coherence, while at the same time they possess only a negligible ductility. Later work by Pumphrey and Jennings of the same school has established that the brittle range does actually show a variation with the silicon content which closely follows the curve for hot-tearing tendency (see Fig. 3). The maximum brittle range is found at 0.6 to 0.7 per cent. silicon.

Residual Liquid and its Behaviour during Freezing: Healing and Accommodation

Most of the foreging discussion has been concerned with the behaviour of the network of primary dendrites formed in solid-solution alloys, and it is now necessary to turn to the part played during solidification by the residual liquid. The importance of the eutectic phase is strongly suggested by the freedom from any tendency to tearing even when cast under conditions exerting a strong restraint on contraction, which is shown by the high-silicon alloys such as AC.6 (BS/STA 7 Services Schedule of Non-Ferrous Metals & Alloys, Group 6: Aluminium and Its Alloys). Clearly, the greater the proportion of eutectic in an alloy, the later it is before the primary dendrites can interlock and the shorter, therefore, is the dangerous brittle temperature range.

It is possible to conceive a process whereby cracks formed in the network of primary dendrites can be healed by the flow of eutectic from other parts of the casting. Fig. 4, taken from an earlier Paper by the Author, shows a section from a somewhat complicated casting in 4 per cent. copper alloy (AC.11). Free contraction was prevented by the presence of baked cores, and it appears that in the earlier stages of freezing, tears were produced in the primary network. Later, eutectic liquid flowed into the crack from a nearby feeder-head, filling the rift and giving the high-copper band seen in the photomicrograph.* Similar bands have been formed in large extrusion billets in DTD.364A alloy, as shown in Fig 5, which is taken from a contribution made by Dr. E. Scheuer and Mr. C. S. Campbell to the discussion on the Author's Paper of 1946. In this case the healing liquid may well have been derived from the metal used for "topping up."

"Eutectic Index"

The eutectic liquid thus plays a most important rôle in determining the hot-tearing behaviour of alloys, and the Author showed that there is a close correlation

* It is interesting to note that such bands, which are not removed in normal heat-treatments, are more absorptive to X-rays than the bulk of the alloy and are therefore seen as *light* areas in the ordinary negative radiograph.

between the hot-tearing tendencies of a range of commercial alloys—some of which were of very complex composition—and the "eutectic index." This quantity, which gives some indication of the proportion of eutectic present, is derived by calculations based on the composition, principally the copper and silicon contents of alloys. There is not the space to describe fully the method of calculating the "eutectic index," although the principles involved are very simple. It is believed by the Author that while the "brittle range" concept of the Birmingham school provides the most complete and satisfying explanation of the observations made on the simpler alloys, the eutectic index provides a ready means of assessing the probable behaviour of the more complex ones often met in practice.

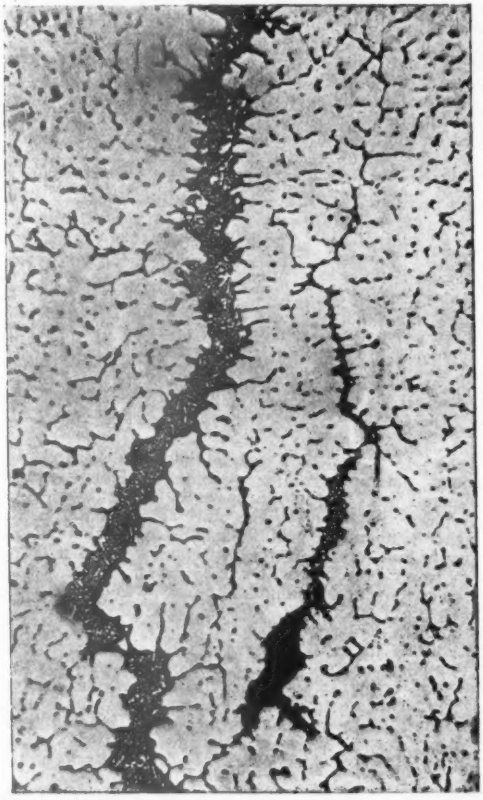


FIG. 4.—INCIPIENT HOT-TEAR IN AC.11 CASTING HEALED BY BAND OF EUTECTIC. (×50).

Pumphrey and Jennings, reviewing the mechanism of solidfication in the light of the Birmingham research, regard the actual healing of rifts in the primary network by the influx of liquid into them, as being normally unlikely to occur and prefer an alternative process referred to as "accommodation." Accommodation enables a solidifying alloy to withstand stresses set up by restraint of free contraction by slight movement of the crystals relative to each other within the partially solid mass. The ease with which this occurs is clearly a function of the proportion of liquid present. This relative movement of the crystals does not involve slip or twinning, such as occurs in the deformation of solid metals, and is limited in its capacity to allow for extension to compensate for shrinkage. When it has proceeded to its maximum degree, tears may occur if there is further restraint of contraction, and in favourable cases these may be filled in by the flow of residual liquid from other parts of the casting or from feeders. This latter process is, of course, healing and, as emphasised by Pumphrey and Jennings, the two processes of healing and accommodation, although different in nature, work together for the same end.

Distribution of Residual Liquid: "Landlocked" and Intergranular Liquid

The proportion of residual liquid is, of course, dependent on the composition of the alloy, but its distribution can be influenced by certain factors over which the foundryman may exert some control. The foregoing discussion of the importance of residual eutectic liquid clearly pre-supposes that it forms a kind of ocean within which the primary dendrites are capable of a limited degree of movement. Eutectic liquid trapped within the arms of the dendrites (or "landlocked" liquid to use the very illuminating term of Pumphrey and Jennings) is of little or no consequence in this respect and any factor which tends to increase the amount of liquid thus trapped at the expense of the intergranular liquid must make the alloy more liable to tearing under the same conditions. The most important factors of this kind are probably the rate of crystal growth and the rate of cooling. The slower the rate of linear growth, the smaller will be the tendency for eutectic to be trapped between the arms of the dendrites. Such a decrease in crystal-growth rate may be brought about in two chief ways:—(*a*) The rate of the heat abstraction may be reduced, or (*b*) crystallisation may begin from a larger number of nuclei, giving a finer grain size.

In practical foundry work, the second is doubtless the more important, and it is well known that fine-grained materials are less prone to hot-tearing than coarse ones. Pumphrey and Jennings suggest that the decrease in the amount of "landlocked" eutectic caused by grain refinement is the main cause of the decreased tendency towards hot-tearing associated with fine-grained materials. Another factor which may contribute to this well-established effect is that accomodation should be easier when the crystals are smaller and more numerous; the analogy with the improved working properties of fine-grained material is immediately seen.

Hot-tearing of Aluminium Alloys

Effect of Dissolved Gas

The second means by which the distribution of eutectic may be influenced depends on the evolution during freezing of gases dissolved in the melt. It is well known how the release of such gases can reduce the risk of cracks developing in the castings and this is utilised in die-casting foundries. This effect was also demonstrated experimentally by the Author, who showed further that it is more marked in alloys with moderate eutectic content and which are inherently less prone to tearing. It may be surmised that the pressure of gas released during freezing will tend to drive the eutectic away from the interdendritic interstices into the intercrystalline spaces. In other words, the action will tend to decrease the proportion of "landlocked" eutectic and, as mentioned previously, this will tend to reduce tearing. It is thus readily understood that the effect will be greater where the amount of eutectic thus displaced is considerable than where only small quantities are concerned.

Practical Conclusions

The above account of the phenomena of hot-tearing in the light of the modern researches suggests that the mechanism of its occurrence is now fairly completely understood. Hot-tears are formed at temperatures above the solidus owing to the restraint of free contraction either by hard cores, or unsuitable die design, or by the prior solidification of certain parts of a complex casting. In essence, the phenomenon is governed by the length of a dangerous brittle range of temperature above the solidus and the length of this range is, in turn, influenced by the constitution of the alloy. It is now clear that beyond a certain alloying content in a binary series, freedom from hot-tearing is promoted by increased additions of the solute element. The content of the alloying element which produces the maximum tendency to hot-tearing approximates to the limit of solid solubility under the conditions of freezing and, indeed, the common aluminium casting alloys are mainly on the higher side of the maximum. Consequently, increase in the alloying contents of the binary casting alloys within the practical range diminishes the tendency to hot-tearing and, for example, alloy AC.10, containing from 9 to 11 per cent. magnesium, is less prone to tearing than AC.5 with 4 to 6 per cent.

Rôle of Silicon

Silicon is probably the most important alloying element present in the modern aluminium-base casting alloys, for, in addition to such essentially binary alloys as AC.6, 8 and 9, amounts significantly greater than those found in the basis aluminium are found in some of the more complex ones, such as AC.1, 4 and 7. In the light of the recent work on the mechanism of hot-tearing it is interesting to consider the reasons for the importance of this element, which is not found in similar proportions in alloys of other metals. In considering the matter, reference will be made to Table I, which gives certain values for points in binary alloy systems based on aluminium as solvent.

TABLE I.—*Some Important Points in Binary Alloys Based on Aluminium.*

Second element	Eutectic temp., deg. C.	Maximum freezing range, deg. C.	Limit of solid solubility* (weight per cent.)	Proportion of second element in the eutectic (weight per cent.)
Mg	451	114	15	32
Cu	548	94	5.5	32
Si	577	45	1.5	12
Zn	380	100	68	95
Ni	633	26	0.005	6

* These values have been taken from the equilibrium diagrams, although it is recognised that the alloys do not freeze under equilibrium conditions.

Table I shows the unusual (and advantageous) features presented by the aluminium-silicon system. Compared with the other systems (apart from the aluminium-nickel alloys), the eutectic horizontal is at a higher temperature and the maximum freezing range is much less. Further, the eutectic occurs at a very much lower percentage. On the basis of these facts, the behaviour of the aluminium-silicon alloys can be examined in the light of the B.N.F.M.R.A. and Birmingham University theories.

According to the Birmingham theory, as expressed by Pumphrey and others, the tendency of an alloy to show hot-tearing is mainly a function of the brittle range of temperature. This range is less than or equal to the freezing range, and the maximum susceptibility to tearing for the series is accordingly related to the maximum freezing range, *i.e.*, 45 deg. C., which is

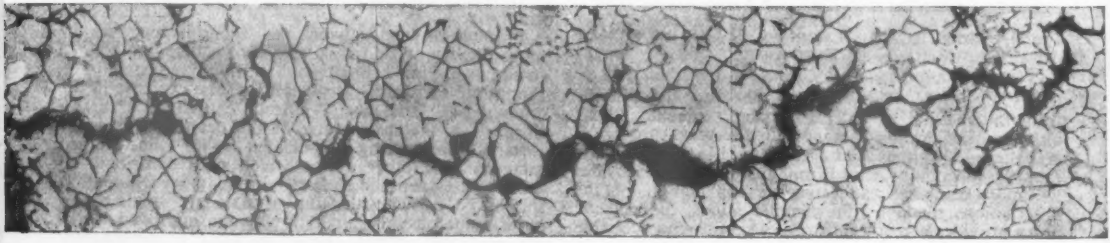


FIG. 5.—HEALED CRACK IN DTD.364A EXTRUSION BILLET. (×30).

much less than the corresponding value for the binary systems containing magnesium, copper or zinc. Again, since the limit of solid solubility is much lower, the practical silicon-containing alloys are on the side where the freezing range is decreasing.

From the point of view of the B.N.F.M.R.A. work, the hot-tearing tendency of an alloy is principally related to the proportion of eutectic in it, while the freezing range is also important. Accordingly, it is to be noted that the amount of silicon present in the eutectic is comparatively small, and consequently even small additions of the element produce relatively large proportions of eutectic. As noted previously, the freezing range of the silicon-containing binary alloys is short.

It is clear, then, that the Birmingham University and B.N.F.M.R.A. theories are in agreement that a high resistance to hot-tearing is to be expected in the aluminium-silicon binary alloys. This agreement is regarded by the Author as being most satisfactory; it follows, of course, from the essentially constitutional nature of the two theories. Consideration of the ternary and higher alloys is, of course, more complicated. For the important case of the aluminium-silicon-copper alloy (AC.4), it was shown in the B.N.F.M.R.A. work that much of the silicon crystallises mostly as the aluminium-silicon binary eutectic. Consequently, the proportion of eutectic remains adequate. In other and more complex alloys, such as AC.7, somewhat similar conditions may obtain.

Grain Size and Gas Content: Two Subsidiary Factors

Constitutional factors are now recognised to be the most important, but some subsidiary ones, principally grain size and gas content, are also operative. These two have been known empirically for some years, but the recent work gives some idea of the way in which they act. In the Author's B.N.F.M.R.A. work, it was suggested that, in a fine-grained structure, the dangerous state at which interlocking occurs between the binary dendrites which have grown from different crystal nuclei is delayed, and therefore the amount of contraction in this condition will be reduced. This view is, of course, in full harmony with the general view of the Birmingham school, and it would be most interesting and valuable if the effect of grain size on the brittle range of temperature and on the temperature of zero coherence could be investigated, using the elegant high-temperature tensile-testing methods developed by Singer. In explaining the grain-size effect, Pumphrey and Jennings suggested that the main reason for it lies in a different distribution of the eutectic as between the interdendritic and intergranular spaces.

The second subsidiary effect—that of gas content—seems, from the small amount of experimental data on the subject, to be more marked in alloys which inherently are more highly resistant to hot-tearing. Here, the view expressed by the Author and by Pumphrey and Jennings are somewhat similar, although the effect envisaged—a re-distribution of the eutectic—is regarded as being on a different scale. The effect of gas content is without doubt the least well established part of the subject, and the problem deserves further study. As a means of reducing the incidence of hot-tearing, grain refinement is preferable, it being simpler to control.

Acknowledgments

The Author wishes to express his thanks to The Aluminium Development Association for permission to publish this Paper and to The Institute of Metals for permission to produce illustrations previously published in their Journal.

APPENDIX I

Methods Employed in the Experimental Study of Hot-tearing of Aluminium Alloys

This appendix is intended to give a short account of the methods used to assess the hot-tearing tendencies of the alloys by making castings and welds under restraint. No reference is made to the tests for the determination of the high-temperature tensile properties of the alloys.

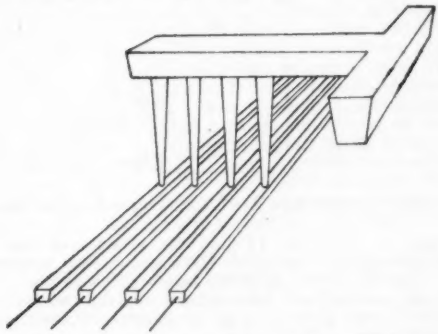


FIG. 6.—HOT-TEAR TEST CASTING IN SAND MOULD

(*a*) *Tests used in the B.N.F.M.R.A. work.*

To assess the hot-tearing tendencies of aluminium casting alloys, two tests were used by the Author. In the first (Fig. 6) four bars were centrally run from pencil runners leading off a horizontal gulley, and their free contraction was restrained by cast-in threaded steel rods, carrying nuts which bore on to the rigid steel moulding box after a greater or less period. Thus the first bar was totally restrained, the second was free to contract for one-tenth of the full amount of shrinkage, the third one-fifth and the fourth three-tenths. The hot-tearing tendencies were assessed by observing which, if any, of the bars were cracked. To avoid confusion with cracking below the solidus, the restraint on all the four bars was relaxed a short time after pouring.

This test, although capable of discriminating between some alloys, was insufficiently severe and a supplementary test was devised in which the alloys

Hot-tearing of Aluminium Alloys

froze in copper dies, free contraction being restrained by flanges at the ends of the vertical barrel (see Fig. 7). Four dies were used, with shanks of dia-

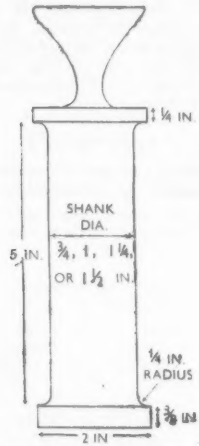


FIG. 7.—HOT-TEAR TEST CASTING IN COPPER DIES.

meter ½, ¾, 1 and 1½ ins., the severity of the test diminishing in that order. The use of this test made it possible to grade alloys between which the sand-mould test had not discriminated and the two methods jointly cover a wide range of degrees of tendency to hot-tearing.

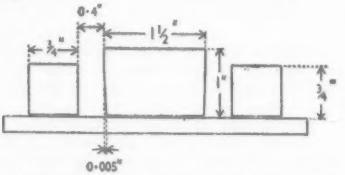


FIG. 8.—MOULD FOR RING CASTINGS.

(b) Tests used in the Birmingham work.

The test devised by Singer and Cottrell and used by Pumphrey, Lyons and Moore is a simple ring made in an open-top iron mould round an iron core of diameter 1½ ins. The width of the ring is 0.4 ins. and its height is about ¾ ins. Fig. 8 shows the mould in cross-section. Tensile stresses are set up by contraction during freezing round the core and may cause cracking if the alloy is brittle at temperatures above the solidus. Quantitatively, hot-tearing is assessed from this test by measuring the total length of cracks formed and the average of totals taken from several castings is calculated. In a second test used at Birmingham, the alloys were rolled to 14 gauge sheet and the cracking observed on welding them under restraint was measured.

APPENDIX II

Papers on the Hot-tearing Tendencies of Aluminium Alloys Published from 1946 Onwards

In this section a brief account is given of the published researches referring to hot-tearing in aluminium alloys. The short summaries are given in order of publication of the original papers.

1. Lees, D. C. G. "The Hot-tearing Tendencies of Aluminium Casting Alloys," *J. Inst. Metals*, 1946, *72*, 343.

The author studied the hot-tearing behaviour of 16 commercial alloys, aluminium of two grades of purity and some simple binary and ternary alloys of aluminium with copper and silicon, using tests in sand moulds and in copper dies (see Appendix I). The tendency towards hot-tearing was found to be related to the constitution of the alloy (particularly the freezing range and the proportion of eutectic present) and to be reduced by grain refinement.

2. Singer, A. R. E., and Cottrell, S. A. "Properties of the Aluminium-Silicon Alloys at Temperature in the Region of the Solidus," *J. Inst. Metals*, 1946, *73*, 33.

Using a Hounsfield tensometer test-piece, it was found that there is a range of temperatures above the solidus in which some of the alloys possess appreciable strength but no ductility. The maximum value of this brittle range was found at 1.8 per cent. silicon. This is close to the maximum solid solubility under equilibrium conditions, corresponding to the longest freezing range in the pro-eutectic part of the series.

3. Singer, A. R. E., and Jennings P. H. "Hot-Shortness of the Aluminium-Silicon Alloys of Commercial Purity," *J. Inst. Metals*, 1947, *73*, 197.

The cracking of alloys containing up to about 12 per cent. silicon was studied in a ring-casting test (see Appendix I) and in a restrained weld test on sheet. The maximum tendency to cracking in casting and welding was found with about 0.7 per cent. silicon.

4. Lees, D. C. G. "Note on the Effect of Dissolved Gas on the Hot-Tearing Tendencies of Aluminium Casting Alloys," *J. Inst. Metals*, 1947, *73*, 537.

Hot-tearing can be reduced by the presence of dissolved gas in the melt before pouring. The effect is stronger in alloys of moderate eutectic content, which are inherently less prone to tearing, than in those more subject to the defect.

5. Jennings, P. H., Singer, A. R. E., and Pumphrey, W. I. "Hot-Shortness of Some High-Purity Alloys in the Systems Aluminium-Copper-Silicon and Aluminium-Magnesium-Silicon," *J. Inst. Metals*, 1948, *74*, 227.

Tests were made on alloys in the range 0 to 10 per cent. copper with 0 to 4 per cent. silicon and 0 to 10 per cent. magnesium and 0 to 5 per cent. silicon. The hot-shortness of the ternary alloys is not so simply related to the constitution as in binary alloys.

(*Continued on page* 220.)

Correspondence

MELTING GALVANISED SCRAP

To the Editor of the FOUNDRY TRADE JOURNAL

SIR,—I should be grateful to any of your readers who would care to express an opinion, based on actual experience or, better still, one who could furnish analytical evidence of the effect of melting scrap galvanised iron castings as part or whole of a cupola charge. It is assumed that the *surface zinc* would not enter the iron, but might not the sub-surface layers of zinc iron alloy be absorbed into the molten pig? I hardly think this query is likely to worry ironfounders in general, but it is of theoretical interest, though one can also visualise an appreciable accumulation of zinc in certain circumstances of repeated re-melting over a long period, with continuing use of this class of scrap. One also wonders whether zinc could exert any beneficial or harmful effects upon (*a*) the iron, by reason of its presence in the reaction zones of the cupola, or (*b*) upon the lining of the cupola itself.—Yours, etc.,

THOMAS B. CROW.

Emery Bros., Limited,
Aston, Birmingham, 6.
August 12, 1949.

GASEOUS ANNEALING OF MALLEABLE

To the Editor of the FOUNDRY TRADE JOURNAL

SIR,—In your issue of January 20 this year, you reported in abstract form a Paper by Mr. H. G. Hall, entitled "Graphitisation in the Malleable Iron Process," which formed the I.B.F. Exchange Paper to the *Association Technique de Fonderie*. A full English version, however, has not been published until quite recently and, since some reference is made in it to the gaseous-annealing process for whiteheart malleable, an opportunity to comment would be appreciated.

Towards the end of his Paper, Mr. Hall makes the following statement: "Since the war, several English malleable ironfounders have installed special batch-type ovens in which the gaseous atmosphere can be developed, circulated and controlled. The high capital cost, fuel cost and necessity for much longer annealing periods in the case of medium- and heavy-section castings, has led to the opinion that rigid metallurgical control of the composition, coupled with greater knowledge of the de-carburising and graphitising reactions in relation to various rates of heating and cooling, is necessary before these installations can successfully compete with the orthodox iron-ore process."

This somewhat sweeping dismissal of the gaseous process, as applied to medium- and heavy-section whiteheart castings, seems to call for an answer on two scores: (*a*) the technical, and (*b*) the economic.

With regard to the technical aspect, it may be stated first that castings with sections up to 1½ in. have for some years past been treated under production conditions in a gaseous installation, with annealing cycles not exceeding 80 hrs. total, and with a resulting product in every way the equal of similar ore-annealed castings as regards ductility and machinability.

Secondly, an extensive experimental programme is at present in progress, and nearing completion, aimed at determining the minimum gaseous annealing cycles necessary to meet the requirements of B.S.S. 309, 1947, Grades 1 and 2. It is hoped to publish the full results of this investigation in the near future, but, meanwhile, the following may be quoted in brief as illustrative of what may be expected from this process, when applied to heavier sections: A batch of some one hundred standard $\frac{9}{16}$ in. tensile test-bars, cast from a large number of different heats, with compositions ranging a good deal wider than commonly met with in commercial practice (Mn, 0.12 to 0.50 per cent., S, 0.02 to 0.35 per cent., and Si, 0.33 to 0.82 per cent.) was annealed in a gaseous furnace, along with a six-ton load of production castings. The cycle was of 75 hrs. over-all length, including a 45-hr. soak at 1,050 deg. C., followed by slow cooling. More than half of these bars gave test results of 25 tons per sq. in U.T.S. or higher, coupled with elongations between 6 and 8 per cent. The average of the whole batch was 27 tons per sq. in. and 6 per cent.

A duplicate set of test-bars was annealed in ore to a typical cycle of 148 hrs. over-all, including 100 hrs. soak at 1,000 deg. C. When tested, none of the ore-annealed bars showed elongations in excess of 6 per cent., and the average results for the whole batch were 28 tons per sq. in. U.T.S. and 5 per cent. elongation. These figures indicate that superior results can be obtained from a 75 hr. gaseous annealing cycle, as compared with an ore-annealing cycle of twice this length, and dispose effectively of Mr. Hall's statement that "rigid metallurgical control of the composition is necessary . . . for gaseous annealing to compete with the orthodox ore process."

Turning now to the economic aspect, the annealing costs per ton in the gaseous process as applied to light-section castings, have been established without fear of contradiction, as the result of several years production experience on a number of installations. The annealing cycle used is commonly 48 hrs. over-all, including 30 to 36 hrs. soak at 1,050 deg., with a net charge weight of between 5 and 6 tons. Typical figures per ton are as follows:—

Item (i) Power Consumption (950 to 1,050 units per ton at ¼d. per unit)	£3	2s.	6d.
Item (ii) Labour (8 man hrs. per ton) and Supervision	£1	5s.	0d.
Item (iii) Furnace maintenance ...		8s.	0d.
Item (iv) Capital charges (15 per. cent. p.a. on installation cost) ...	£2	0s.	0d.
Total cost per ton ...	£6	15s.	6d.

For medium- and heavy-section castings, requiring the maximum physical properties, it may safely be assumed, in the light of the test results referred to above, that the necessary annealing cycle will not be much in excess of 80 to 85 hrs., including 55 to 60 hrs.' soak followed by slow cooling. This increase in soaking time will, of course, result in a higher power consumption; the increase, however, is not as much as

Correspondence

might be expected, since with a well-insulated furnace such as is employed in the gaseous process, the main consumption is in bringing the load up to temperature; further, a somewhat bigger load (6 to 7 tons) can normally be accommodated with heavier castings, which tends to reduce the consumption per ton. A typical figure, determined in practice, is 1,100 to 1,200 units per ton. Items (ii) and (iii), labour and maintenance, will not be altered appreciably as compared with the shorter cycle, the maintenance charge being, if anything, slightly lower. The output of the furnace, however, will be reduced from the 16 to 20 tons per week obtainable on short cycles, to 10 to 14 tons, thus increasing the capital charges from £2 to about £3 per ton. The resulting total cost per ton is about £8 5s., a percentage increase of approximately 20 per cent., as compared with short-cycle operation on light castings.

Mr. Hall is no doubt well aware of the general level of annealing costs in the whiteheart industry using the orthodox ore process, and if the gaseous process is competitive on light castings, as has now been abundantly proved, it is quite certain that it will prove to be equally so for medium and heavy castings. The matter will be confirmed in a practical manner in the course of the next 12 months, during which a large number of gaseous installations, many of which will be handling heavy section work, will be put into operation. —Yours, etc.,

P. F. HANCOCK,
Chief metallurgist.

Birlec, Limited,
Tyburn Road,
Erdington, Birmingham, 24.

International Nickel's Earnings

The report of the International Nickel Company of Canada, Limited, and its subsidiaries for the quarter ended June 30, 1949, shows a net profit in terms of U.S. currency of $8,220,950, equivalent, after preferred dividends, to 53 cents a share on the common stock. This compares with a net profit of $12,762,467, equal to 84 cents a share, in the previous quarter and with $9,819,301, or 64 cents a common share, in the second quarter of 1948.

For the six months ended June 30, 1949, net profit was $20,983,417, equal to $1.37 a share, compared with $20,235,006, or $1.32, in the corresponding period a year ago.

Below the Solidus in Castings and Welds in Aluminium Alloys," *J. Inst. Metals*, 1948, *75*, 257.

The occurrence of cracking below the solidus (in the range of 200 to 400 deg. C.) is thought to depend on the ductility of the metal, the stress conditions during cooling and on the amount of cracking which took place above the solidus. Such cracking can only take place in alloys of low ductility, and the authors conclude that it should be rare in practical conditions of casting.

Hot-tearing of Aluminium Alloys

(*Continued from page* 218.)

6. Jennings, P. H., and Pumphrey, W. I. "A Consideration of the Constitution of Aluminium-Iron-Silicon Alloys and Its Relation to Cracking above the Solidus," *J. Inst. Metals*, 1948, *74*, 249.

The authors review the available information on the constitution of the ternary alloys and show that the higher tendency to hot-tearing shown when the silicon content exceeds that of the iron is related to an increased freezing range.

7. Pumphrey, W. I., and Moore, D. C. "Cracking During and After Solidification in Some Aluminium-Copper-Magnesium Alloys of High Purity," *J. Inst. Metals*, 1948, *74*, 425.

Alloys containing up to 12 per cent. copper and 12 per cent. magnesium were studied, using the methods of paper (3). Cracking at temperatures below the solidus was distinguished from hot-tearing, and it was shown that those alloys which are least subject to hot-tearing are the most susceptible to cracking below the solidus under severe conditions of restraint.

8. Pumphrey, W. I., and Lyons, J. V. "Cracking During the Casting and Welding of the More Common Binary Aluminium Alloys," *J. Inst. Metals*, 1948, *74*, 439.

Studies were made, using the methods of paper (3), on alloys of aluminium with silicon, copper, magnesium, iron, manganese and zinc. In all the systems examined, an initial increase in cracking occurs on adding the alloying element to super-purity aluminium. A maximum in the curve is followed by a subsequent decrease to zero at a higher content.

9. Pumphrey, W. I., and Jennings, P. H. "High-Temperature Tensile Properties of Cast Aluminium-Silicon Alloys and Their Constitutional Significance," *J. Inst. Metals*, 1948, *75*, 203.

In this work the authors determined the tensile properties of alloys made from super-purity aluminium and containing up to 12 per cent. silicon. Tests were made both during cooling from the liquid state and after rapidly re-heating the chill-cast alloys. There is a region at relatively low temperatures in which the strength falls gradually with increasing temperature; this is succeeded by a higher-temperature portion in which the alloys show a brittle intercrystalline fracture, until a temperature is reached when there is so much liquid that coherence is lost. The brittle range of temperatures is that between the point of zero coherence and the effective solidus temperature under the relevant conditions.

10. Pumphrey, W. I., and Jennings, P. H. "A Consideration of the Nature of Brittleness at Temperatures above the Solidus in Castings and Welds in Aluminium Alloys," *J. Inst. Metals*, 1948, *75*, 235.

This paper gives a detailed account of the mechanism of solidification and the mode of tearing as understood by the Birmingham school.

11. Pumphrey, W. I., and Moore, D. C. "A Consideration of the Nature of Brittleness at Temperatures

Acid-Resisting Silicon Iron

High-duty Applications

*By R. V. Riley, Ph.D., B.Sc., A.I.M.**

Iron silicon alloys containing upwards of 14 per cent. silicon have been well known in the chemical industry since the discovery of their excellent acid-resisting qualities by Jouve, a French metallurgist, in 1908. Despite the discovery of stainless steels, high-chromium irons, nickel-silicon and nickel-molybdenum alloys and the continued developments in the application of lead, ceramics, fused silica, noble metals and plastics, silicon iron is still favoured as a constructional material for acid-resisting plant.

Many industries demand constructional materials which can claim a high degree of resistance to corrosive media coupled with metallic properties. The unique combination of these properties in silicon iron is certainly the main reason for its continued and ever widening popularity in the chemical and kindred trades. Hitherto in most of the industrial applications, castings of acid-resisting silicon iron have been employed only in a relatively unstressed condition, working either at atmospheric, or at the most, water-gauge pressures of not more than a few inches. It may not indeed be common knowledge that this alloy can be used under other conditions. Of recent years, however, owing to the great improvements in its consistency, strength and reliability, silicon iron is becoming increasingly used for plant working at relatively high temperatures and pressures.

Silicon Iron v. Sulphuric Acid

From a corrosion resistance point of view, silicon iron occupies the prime position as the metal best suited for the manufacture of equipment for sulphuric acid concentrating plant. Throughout two world wars it has stood alone as the most satisfactory commercially available material for this type of acid plant. Recent developments in chemical engineering have resulted in the production of a new type of sulphuric acid concentrator which makes very severe demands upon the alloy. Simon Carves are responsible for the introduction to this country of this plant in which weak sulphuric acid is brought up in strength to 93 per cent. under fume-free conditions by means of a vacuum concentrator. The contract for the silicon iron parts of these concentrators was given exclusively to Bradley & Foster, Limited, Darlaston, S. Staffs, where the various castings were executed in Hypersilid 14 to 16 per cent. Si alloy.

*Research Manager, Staveley Iron and Chemical Company, Limited, near Chesterfield.

Heater-tube Castings

A vital part of the concentrator, is a heater tube, having a closed end, totally immersed dilute sulphuric acid and carrying live steam at about 100 lb. per sq. in. Two types of heater tube have been made in silicon iron, the first were 5 ft. long by 7 in. outside diameter, and the second series were 6 ft. long × 7 in. outside diameter. The finished casting, shown in Fig. 1, is an example of the larger type of tube, weighing 318 lb. The minimum thickness of this heater tube at any point was $\frac{1}{4}$ in.; maximum was $\frac{5}{16}$. The variation in wall thickness between any four places at any selected section had not to exceed $\frac{1}{8}$ in. provided none of these measurements fell outside the former limits of thickness. The tolerance on wall thickness for the un-machined sand casting was therefore $\pm\frac{1}{16}$ in. The maximum permitted departure from the straight was $\frac{1}{4}$ in. over the six foot length of tube.

The open end of the tube was provided with a flange, $11\frac{1}{2}$ in. diameter, and a projecting spigot which terminated in a cone end-joint. The flange and jointing section were machined on all faces. Silicon iron is a very hard alloy and the machining of this end was a grinding operation. Each casting was identified by a serial number cast on the nose-end and a complete record of inspection data was filed.

Foundry Technique

It is not permissible to make silicon iron castings with chaplets. The whole of the core for this blind-end tube had to be located and secured in position from the open end. To work to the desired fine tolerances,

FIG. 1.—SILICON-IRON HEATER TUBE.

Acid-resisting Silicon Iron

necessitated special mechanical arrangements to hold the core rigidly in position during casting. The special moulding-box and core assembly shown in Fig. 2, was used. This consisted of a two-part box of hexagonal cross-section having open ends which were accurately squared and machined to provide locating faces for a loose nose-end moulding box at one end and the special core barrel collet at the other.

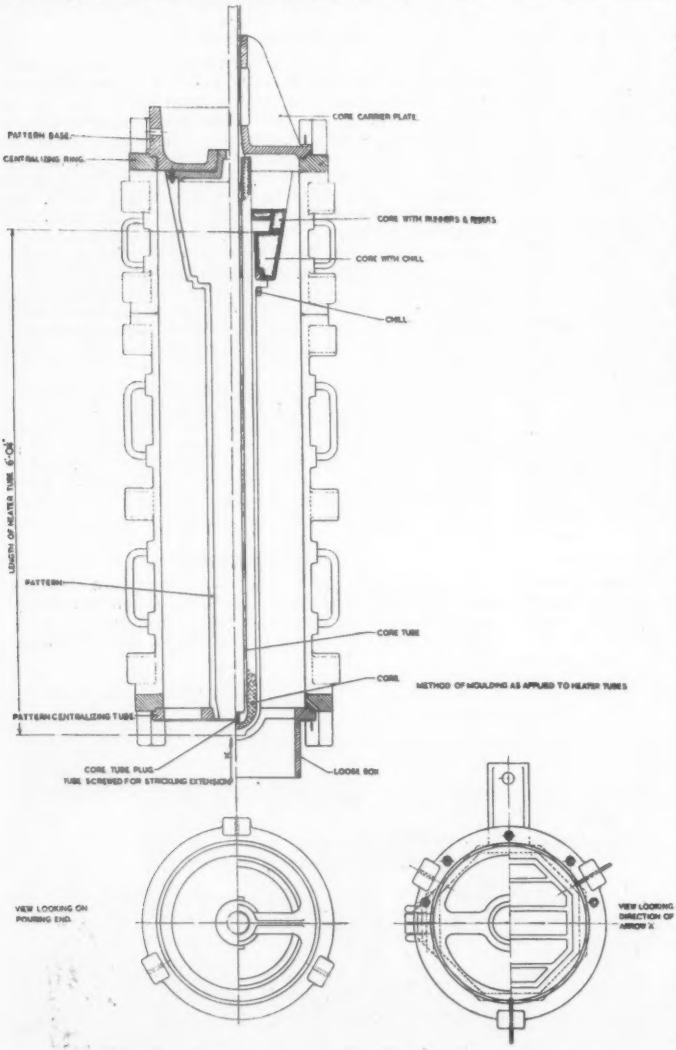


FIG. 2.—MOULDING BOX AND CORE ASSEMBLY FOR HEATER-TUBE CASTINGS.

The core was made by loam moulding on a machined core barrel which worked in machined bearings. The loam board was a fixture. A loose plug of the same diameter as the core barrel was provided, which served as one of the journals during core-making and for handling purposes during stoving. This plug was screwed from the end of the core barrel just prior to setting up in the mould, the hole being made up with loam. Wood-wool rope, wound on to the core barrel, served as a foundation for the loam, which was of special consistency calculated to collapse readily after the pouring of the iron. The moulding box was arranged to stand on end in a pit suspended from brackets on the side, leaving 3-ft. clearance at the bottom.

Fig. 3 shows the moulding box assembled in the pit. The mould was hand rammed around a full-length steel pattern located in the collet at the top and a removable ring at the bottom. A natural sand was used, blended to give a dry-sand mould having adequate strength when stoved, but readily collapsible after pouring. The mould was rammed with the detachable nose-box in position. This small box was removed from the mould from underneath so as to enable the core to be set accurately. The nose-end mould was replaced for casting. The flange and cone contour of the open end of the tube were obtained by means of oil-sand core, which also served as a pouring basin for filling the mould *via* pencil sprues.

The mould was cast with silicon iron at a temperature of 1,320 deg. C. (optical) and exactly seventeen minutes later the core barrel was drawn. The mould was removed from the pit, placed on its side on the foundry floor and then the box was opened so as to ease the sand around the flange. The casting was then left to cool slowly in the box. The casting was taken from the moulding box when cold and fettled by grinding. It was then ready for inspection and testing.

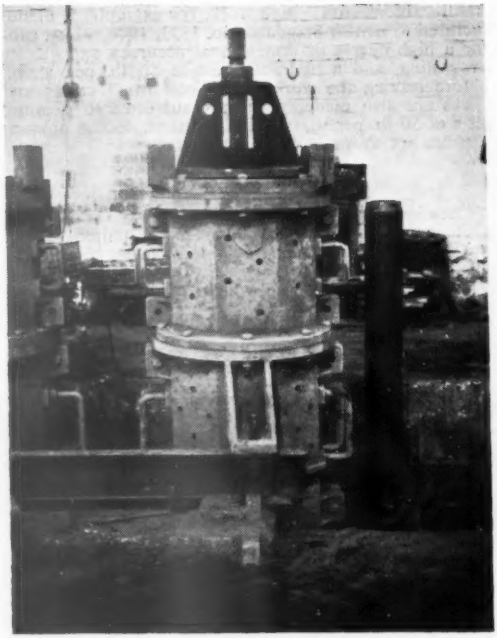


FIG. 3.—MOULD ASSEMBLED FOR CASTING.

Inspection and Testing

Each casting was subjected to an extremely thorough and extensive programme of inspection and testing by the manufacturers and a final inspection in the presence of representatives from Simon Carves, a boiler insurance company and the customer. The first inspection of the casting was made before machining by the work's inspector. Dimensional checks were carried out, using a specially-designed wall-thickness measuring machine. The quality of the inside of the tube was then approved by a detailed examination with the Foster Intrascope, an optical device which enables the eye to see every part of the internal surface of the tube, including the closed end. A casting passing this first inspection was then hydraulically tested at 100 lb. per sq. in. and approved for machining.

When the grinding of the flange and open end of the tube was finished, the casting was transferred to an acid pickling tank (Fig. 4). The pickling process was carried out at 80° C. in 30 per cent. sulphuric acid until all effervescence ceased. Then followed a final check upon dimensions in the presence of outside inspectors and a pressure test with kerosene under 400 lb. per sq. in. for 30 minutes. No pressure drop under this test was allowed.

Despite the very stringent inspection and testing programme, an extremely formidable specification for castings in any metal, large numbers of heater-tube castings have been produced. Some 152 short tubes and 168 long tubes have been supplied to the customers. The first batch, which, it is understood, have given complete satisfaction to the user, was completed in July, 1944. The last order for the longer tubes was finished early this year, some six months after the acceptance of the contract.

Metallurgical Considerations

Silicon iron for high-duty castings requires very careful preparation. Electric-furnace melting of the iron is practised at Bradley & Foster, Limited. First, an ingot is made from carefully selected raw materials, refined pig-iron, steel scrap and high-grade ferro-silicon. It is very important to select only raw materials known to be low in hydrogen. The ingot is remelted together with foundry scrap in a 30-cwt. three-phase direct-arc furnace.

The metal for castings must be checked for "gassiness" before using. This practical test is made by the pouring of a sampling spoonful of molten iron into a prepared sand mould; during solidification its surface is carefully watched for signs of bleeding back. To avoid porosity it is important to keep the hydrogen content of silicon iron below 2 mls. per 100 gms. It is equally important to prevent the approved iron from making subsequent contact with any wet patches on the lip of the ladle or with damp runner bushes. Furnace patching must be carefully dried-out before the unit is used melting silicon iron.

It is also important to keep the carbon content of the iron within the optimum range, which, with the Hypersilid alloy, is 0.60 to 0.65 per cent. This ensures the absence of kish inclusions on the one hand and undue shrinkage on the other. For adequate resistance to corrosion, the silicon content is kept about 14.5 per cent. The manganese and phosphorus are 0.6 per cent. and 0.2 per cent. respectively.

The physical and mechanical properties of Hypersilid alloy are now firmly established and are shown in Table I. It is convenient to compare silicon iron

FIG. 4.—ACID PICKLING TANK.

Acid-resisting Silicon Iron

TABLE I.—*Physical and Mechanical Constants of Chemical Ware.*

	Hyperalid 14/16.	Cast Iron.	Stoneware.
Weight in pounds per cub. ft. ..	428	445	136
Density in grams per cub. cm. ..	7.0	7.3	2.2
Melting point, deg. C.	1,250	1,200	1,450
Specific heat	0.130	0.115	0.20
Coefficient of expansion (× 10⁶) ..	12.0	12.1	4.5
Thermal conductivity (cals. per cm. per sec.)	0.078	0.110	0.0023
Electrical resistivity (micro-ohms per cub. cm.)	50	45	—
Hardness (Brinell)	450	180	—
Tensile strength (tons per sq. in.)	10.0	15.0	1.0
Transverse strength (tons per sq. in.)	18.0	30.0	—
Modulus of elasticity (lb. per sq. in. × 10⁶)	17.0	19.0	—

with cast iron and with stoneware, as all these three materials are commonly used in the construction of chemical plant. When the outstanding acid-resisting qualities of "silicon iron" are considered along with the mechanical properties as revealed in the Table, the reason for the success of this alloy in the chemical industry is obvious.

British Standard "Silicon-iron" Castings

The heater-tube casting, described was one which required more than ordinary care and ingenuity in manufacture and was subjected to very severe inspection and testing. "Silicon iron" manufacture in this country is, however, on a very sound footing, and many castings are made in the course of an ordinary day's work which match this example in complexity or degree of reliability expected in use.

All "silicon-iron" pipe work, for example, is manufactured to British Standard No. 1333, 1946, which calls for a high degree of dimensional accuracy and quality of casting, and a hydraulic test to 50 lb. per sq. in. before leaving the works. "Silicon-iron" valves and cocks are also made, which are subjected to pressure tests of 50 lb. per sq. in. with kerosene. Some unusual castings are shows in Figs. 5 and 6.

Concluding Remarks

Chemical plant in which "silicon iron" can be advantageously used need no longer be limited to low working pressures. The silicon-iron heater tube, using steam at 100 lb. per sq. in., is an established fact. Other plant is known in which satisfactory performance has been obtained under conditions of mechanical stress, and there is little doubt that a more widespread use of this valuable corrosion-resistant alloy may be contemplated.

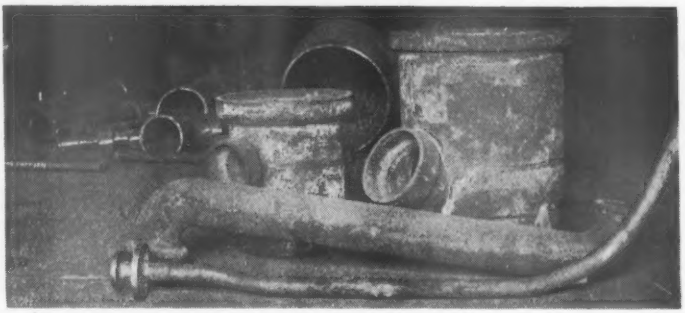


FIG. 5.—COMPLEX CASTINGS IN ACID-RESISTING SILICON IRON.

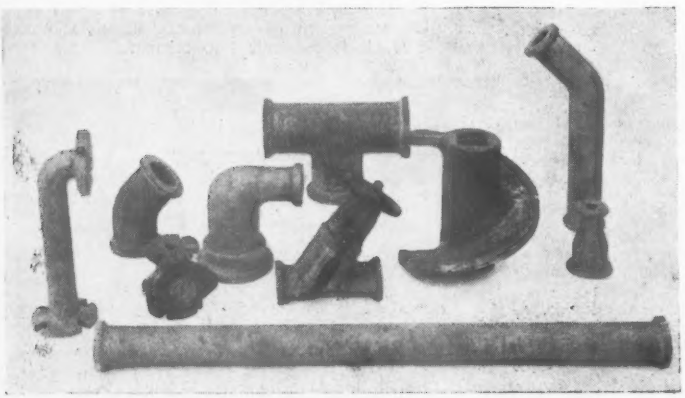
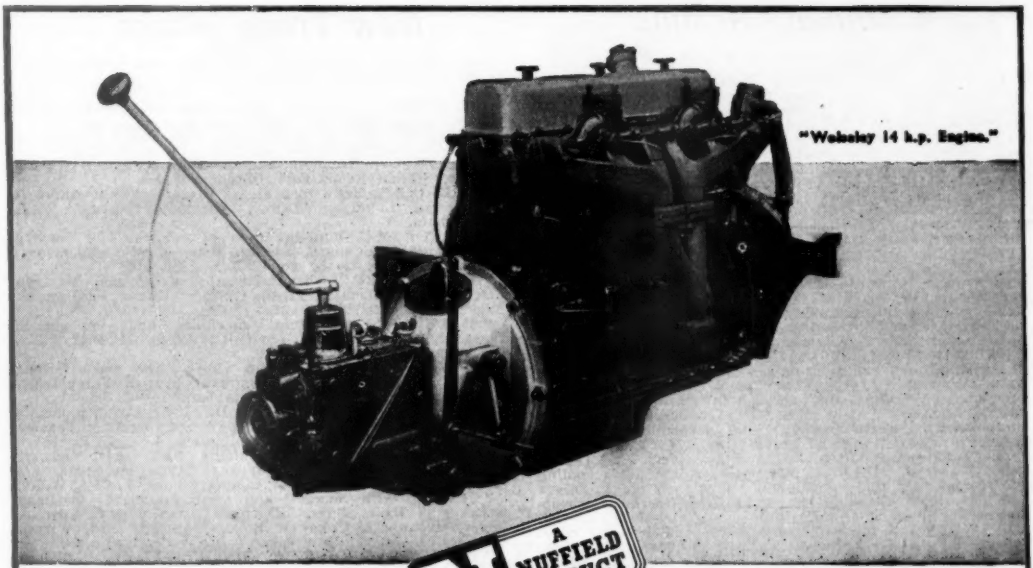


FIG. 6.—GROUP OF SILICON-IRON ACID-RESISTING CASTINGS.

Acknowledgments

Acknowledgments are made to Simon Carves, Limited, Stockport, and to Bradley & Foster, Limited, Darlaston, for permission to publish this article.

MR. NORMAN S. MOTT, writing in "Materials and Methods," recommends the use of C.F.-8M as being superior to the ordinary 18:8 stainless steel as applied to castings. This composition, now widely used in the United States, carries between 2 and 3 per cent. molybdenum. It is said to reduce the susceptibility to intergranular corrosion, and increase resistance to stress-corrosion cracking.



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Company Results

(Figures for previous year in brackets.)

F. H. LLOYD & COMPANY—Consolidated profit and loss account for the year to March 31 shows group trading profit, £318,132; other income, £1,314; to tax, £140,700; depreciation and obsolescence, £41,153, etc.; net profit, £132,872; provision by a subsidiary not required, £3,433; to provision for income tax, 1948-49, £21,134; general reserve, £27,064; reserve for increased cost of replacement of fixed assets, £50,000; dividends to outside shareholders' subsidiary company, £447 net; dividend of 10% (same); forward, £35,679 (£26,344).

NEWTON BROS. (DERBY)—Trading profit to March 31, £84,421 (£81,974); investment income, etc., £1,891 (£1,924); to directors' remuneration and pensions contributions, £8,169 (£7,375); directors' fees, £1,500 (same); depreciation, £7,247 (£5,181); tax, £40,503 (£38,061); net profit, £28,893 (£31,781); credits from previous years and settlement of outstanding royalties matter reported on in previous accounts, £17,520 (nil); brought in, £15,092 (£9,173); to stock contingency reserve, nil (£10,000); general reserve, £35,000 (£5,000); dividend of 17½% and bonus of 7½% (same); forward, £15,644 (£15,092).

NEWMAN & WATSON—Consolidated trading profit to March 31, including rents and profit on sale of plant, £89,567 (£64,421); to depreciation, £4,049 (£4,379); leasehold redemption policy premium, £331 (nil); bank and loan interest, £5,964 (£4,622); special expenses, £2,699 (£898); legal costs, nil (£282); off preliminary expenses, nil (£172); off goodwill, £460 (£100); income tax, £30,800 (£25,985); profits tax, £11,000 (£8,900); net profit, £34,274 (£19,083); to outside shareholders, £299 (£217); general reserve, £18,000 (£7,500); holding company's trading profit, including rents and profit on sale of plant, £63,137 (£45,709); to depreciation, £1,999 (£1,823); leasehold redemption policy premium, £331 (nil); bank and loan interest, £5,485 (£3,975); special expenses, £2,699 (£898); legal costs, nil (£282); off goodwill, £460 (nil); income tax, £22,000 (£17,285); profits tax, £6,000 (£5,100); net profit, £24,173 (£16,346); to general reserve, £8,000 (£7,000); bad debts, £7,000 (nil); dividend of 7½% (same); forward: consolidated £20,551 (£17,557), parent £11,921 (£8,729).

METAL INDUSTRIES—Group profit and loss account to March 31 shows trading profits of subsidiaries, £845,039 (£659,885); dividends from quoted investments (gross), £185,063 (£185,241); dividends from unquoted investments (gross), £14,340 (£626); interest (gross), £267 (£152); transfer fees, £151 (£387); M.I. dividends and interest from subsidiary companies, £423,494 (£326,584); M.I. profit, £622,279 (£511,965); to depreciation, £104,712 (£93,810); office expenses, £46,154 (£31,986); audit, £2,452 (£2,322); group profit, before taxation, £891,542 (£718,173); to profits tax, £151,596 (£120,604); future income tax, £231,867 (£199,713); income tax on interest and dividends, £83,231 (£94,019); net profit, £424,849 (£303,837); to subsidiary company pre-acquisition profits and transfer to reserve, nil (£27,777); to outside shareholders, £15,349 (£9,335); net balance, £409,500 (£266,725); including directors' fees of £2,750 (£2,600), cost of dividends is £182,265 (£180,826); surplus for year, £227,235 (£85,899); brought in, £279,223 (£193,324); adjustments, £22,889 (nil); the total emoluments received by directors of Metal Industries were £43,600.

ASSOCIATED BRITISH ENGINEERING—Consolidated accounts to March 31 show dividends from former subsidiaries, £80,000; dividends on other investments, £27,414; interest, £14,029; sundry income, £2,416; subsidiaries' trading profits, less loss—incorporating results of two subsidiaries for one year, and one for nine months, the fourth not trading—£1,621; to management expenses of holding company, £8,377; bank interest, £13,260; depreciation and off fixed assets, £6,542; loss on sale assets of a subsidiary, £3,211; auditors' remuneration, £626; preference arrears, Henry Meadows, £8,250; income tax on dividends, interest, etc.—less £1,610 over provision by subsidiary in previous year—£41,408; leaving £43,806; brought in, £16,378; available after deducting subsidiaries' debit of £4,720, £60,184; dividend of 12%; profit of subsidiary for year, eliminated on consolidation in reduction intangible assets, £2,925; forward: holding company credit £48,079, subsidiaries' debit, £9,470. A note states that profits tax payable by the company to March 31, not yet agreed, but estimated at £61,000, has not been provided in these accounts, being recoverable in full from former subsidiaries under agreement made.

New Trade Marks

The following applications to register trade marks appear in the "Trade Marks Journal":—

The following applications to register trade marks appear in the "Trade Marks Journal":—

"SIRRAM"—Metal hearth furniture. MARKIS'S, LIMITED, 16, Cumberland Street, Birmingham, 1.

"ROTAVATOR"—Agricultural implements. ROTARY HOES, LIMITED, Station Road, East Horndon, Essex.

"KARLITE"—Metal road studs. HARBERRY ENGINEERING & CONTRACTING COMPANY, LIMITED, 924, Woodborough Road, Nottingham.

"POLYGRAM"—Moulding powders and sand, for foundry use. POLYGRAM FOUNDRIES, LIMITED, Power Road, Gunnersbury, London, W.4.

"FERRAXCUBE"—Chemical compounds of iron. MULLARD ELECTRONIC PRODUCTS, LIMITED, Century House, Shaftesbury Avenue, London, W.C.2.

"MARBEET"—Agricultural machines and implements. BLACKWELDER IRON WORKS, c/o Gill, Jennings & Every, 51-2, Chancery Lane, London, W.C.2.

"METLOYS"—Common metal alloys (other than ferrous alloys). METALS & ALLOYS (BIRMINGHAM), LIMITED, Forge Lane, Kingsbury Road, Minworth, Birmingham.

"SEACLIFF" (LIGHTHOUSE DEVICE)—Common metals and alloys, etc. CHARLES CLIFFORD & SON, LIMITED, Fazeley Street Mills, Fazeley Street, Birmingham, 5.

"SIMAR"—Agricultural machinery and parts. SOCIETY INDUSTRIELLE DE MACHINES AGRICOLES ROTATIVES SIMAR, c/o George Ham & Company, 93-94, Chancery Lane, London, W.C.2.

"ZINTEC"—Unwrought and partly-wrought common metals and their alloys. BRITISH COATED SHEETS, LIMITED, Mersey Ironworks, Cromwell Road, Ellesmere Port, Wirral, Ches.

"POLOCAST PRODUCT" (DEVICE)—Electrical fittings included in Class 9, all being pressure die-castings in zinc base alloy. ALEXANDER POLLOCK & COMPANY, 14, Antigua Street, Edinburgh.

"WILCOLOY"—Unwrought and partly-wrought common metals or alloys. H. A. WILSON COMPANY, c/o Cruikshank & Fairweather, 29, Southampton Buildings, Chancery Lane, London, W.C.2.

"FLOTECTIC"—Common metal alloys in the form of rods or wires for welding, brazing and soldering. EUTECTIC WELDING ALLOYS COMPANY, c/o Albert L. Mond & Thiemann, 14-18, Holborn, London, E.C.1.

Increases of Capital

Details of increased capital have been announced by the following companies:—

MIDLAND ROLLMAKERS, LIMITED, Wolverhampton, increased by £250,000, in £1 ordinary shares, beyond the registered capital of £10,000.

THOMPSON BROS. (BILSTON), LIMITED, founders, engineers, etc., increased by £180,000, in 5s. ordinary shares, beyond the registered capital of £170,000.

JAMES MILLS, LIMITED, ironfounders, engineers, etc., of Tyseley, Birmingham, increased by £33,000, in £1 ordinary shares, beyond the registered capital of £2,000.

AEROPLANE & MOTOR ALUMINIUM CASTINGS, LIMITED, Erdington, Birmingham, increased by £75,000, in £1 5½ per cent. redeemable cumulative preference shares, beyond the registered capital of £100,000.

G. N. HADEN & SONS, LIMITED, heating and electrical engineers, etc., of London, W.C.1, increased by £525,000, in 350,000 5 per cent. cumulative preference shares of £1 and 700,000 ordinary shares of 5s. each, beyond the registered capital of £225,000.

DARTMOUTH AUTO CASTINGS, LIMITED, Smethwick, increased by £50,000, in £1 shares, beyond the registered capital of £75,000. On February 4, 1949, Birmid Industries, Limited, held 64,400 shares. A further 60,000 shares were allotted to that company on June 30.

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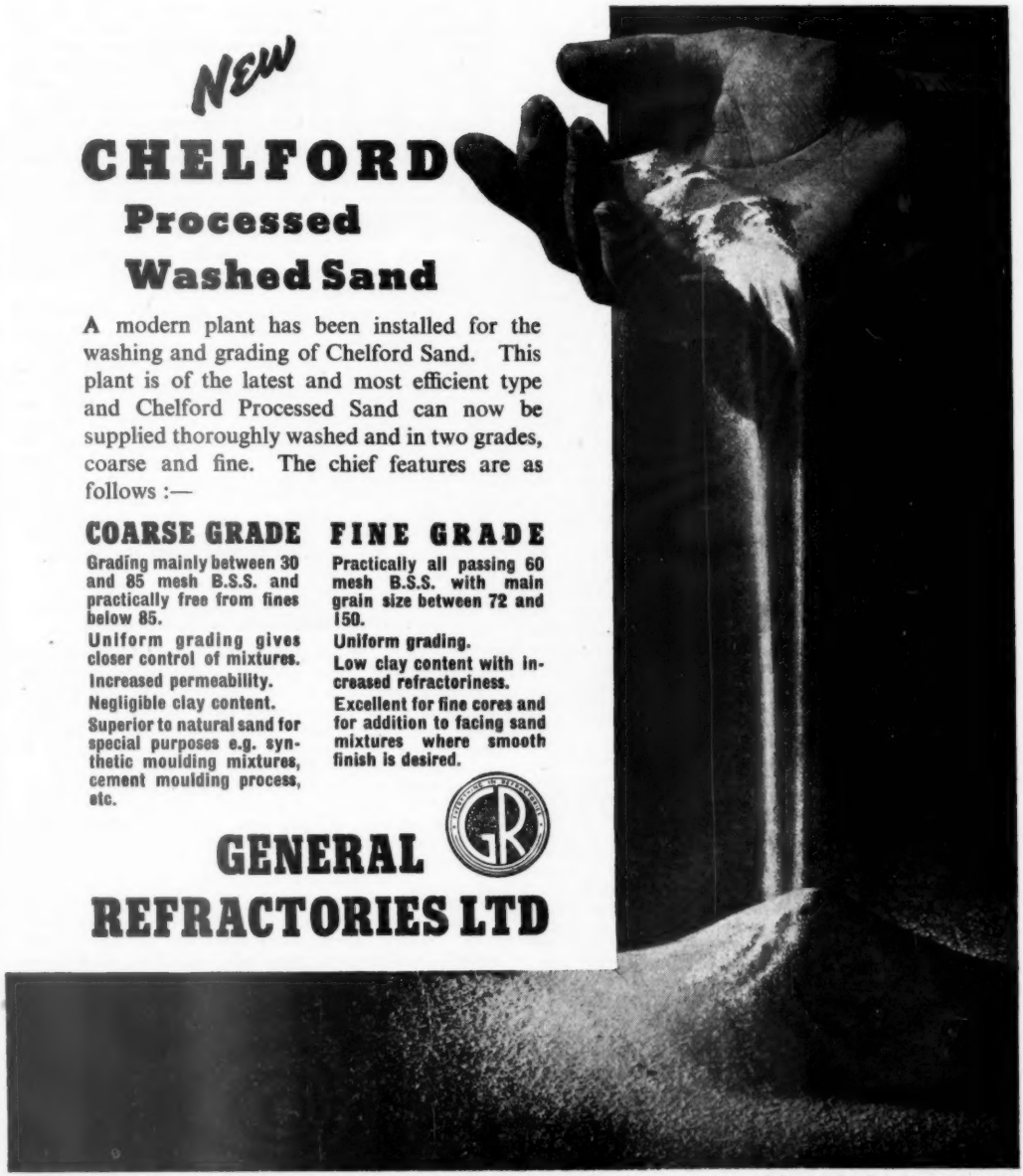

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388

Raw Material Markets

Iron and Steel

Foundries are now settling down after the holidays and have a reasonable amount of work on hand to ensure fairly satisfactory outputs. Although demand is not heavy, a number of foundries are fully occupied, judging by their demands for pig-iron which cannot be met in full. This applies particularly to some of the light and engineering foundries. Production of high-phosphorus pig-iron is fully maintained and total outputs are accepted by the light foundries; indeed, many of them call for increased tonnages. Available supplies are barely sufficient for their needs and, until additional furnaces are in blast, increased quantities will not be forthcoming.

The general engineering, speciality and jobbing foundries are steadily employed, with the jobbing foundries mostly in need of new business. Requirements of pig-iron are being met to some extent by producers of the low- and medium-phosphorus grades, and available supplies of hematite are also accepted readily. The production of hematite is mostly in the low-silicon grades and usually necessitates the use of ferro-silicon. Refined iron is also taken up in some proportion by these foundries and makers can usually meet requirements both as regards tonnage and analysis. Parcels of this grade continue to be exported.

Cupola scrap supplies are on a better scale, but there is no difficulty in disposing of available tonnages. Deliveries of foundry coke are being maintained and allow of some stocks being built up. Hard furnace coke for heating purposes and core-oven use is plentiful and other requisites, including ganister and limestone, come forward freely. Those foundries utilising ferro-alloys can usually obtain their needs without difficulty.

Business at the re-rollers is generally satisfactory, both as regards orders and steel supplies with which to implement them. The light re-rollers are obtaining good outputs of the lighter gauges of sections, bars and strip, which, while more nearly approaching requirements, are not in excess of demand, particularly the very small bars for which there is a heavy call. The prospect of obtaining supplies is, however, far more satisfactory than it has been for some time, due to the improved supplies of the smaller sized billets which are coming to hand from the Continent. Sheet mills are particularly active and their outputs of both black and galvanised sheets are readily absorbed. Improved supplies of sheet bars are enabling them to deal more effectively with their commitments. Heavy mills are also obtaining good outputs.

Non-ferrous Metals

The firm tone of metals in New York persists and the trend on Wall Street is upwards. Last week lead, after closing at 14¼ cents, moved to 15 and 15⅛ cents per lb. at the week-end. As usual the Ministry of Supply took swift action and raised its quotation by £2 2s. 6d. to £87 5s. per ton. Lead scrap followed the tendency of the virgin metal and was marked up by 25 points to 11.25 to 11.75 cents per lb. In the United Kingdom there is not a lot of trade in virgin lead, for the quota system is still in force and it is probable that consumers secured their cover for the third quarter early in July, when the price was much lower than it is to-day. It must be supposed that in America lead is once again rated as a scarce metal for the rise has now been from 12 to 15 cents, an advance of 25 per cent., and the authorities here have, of course, followed the advance closely. Nevertheless, there is no impression that lead is in short supply in Britain; stocks at the half-year were higher than for some time past. Since the rationing scheme is apparently to continue, a condition of plenitude looks like developing in the U.K., unless the Government cuts down its purchases of lead from overseas.

Judging from the reports of the dollar situation, it certainly looks as if imports into the U.K. are going to be reduced during the coming months, and metals will doubtless be obliged to bear their share in this cut. For many years now a fairly high proportion of our non-ferrous metal supplies have come from the dollar area and this applies particularly to copper. Both Canada and Chile have, over a long period, sent to Britain large and important tonnages of copper, although from the latter country very little came in during the war years. This year and last year, however, a considerable tonnage of copper was received from Chile in the form of blister and fire-refined grades. The quality shipped from Canada is all electrolytic.

Aluminium Price Increased

The price of virgin aluminium in ingot form has been increased from £90 to £93 per long ton, delivered into consumers' works, with the addition of £2 10s. per ton for metal in notch bar form. The Ministry of Supply states that the increase is due to a rise in the average cost of current supplies. The new price applies to metal of a purity of 99 to 99.5 per cent. inclusive.

The existing premiums for higher purities will be payable in addition as follows:—Minimum, 99.6 per cent., £8 per ton; 99.7 per cent., £12; 99.8 per cent., £17; 99.9 per cent., £50; 99.99 per cent., £100.

Castings. The Technically Controlled Castings Group (consultants and secretaries, John Gardom & Company, Ripley, Derbyshire) has sent us a 12-page beautifully-illustrated brochure covering castings in steel, malleable, grey and alloyed cast iron, and non-ferrous material. The group trade mark is "Teconic"—a portmanteau word for technically controlled and inspected castings. The choice of the illustrations has been excellent and the layout of the central double-page spread is impeccable, the draught board effect being particularly pleasing. The use of yellow, however, is questionable, as very few people can see this colour, when devoid of any red, without distinct strain. Yellow is really suitable for a background colour, but is ineffective as letterpress.

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Company News

The paragraphs below have been extracted from statements circulated to shareholders, from speeches made at annual meetings, and other announcements.

General Electric Company, Limited:—The directors state that sales have continued at a high level, but there has been a definite fall in some departments in the value of orders received. The increase in the value of stock and work in progress results largely from the company's heavy order-book for capital goods. The decrease in the home demand for certain consumer goods has also led to some increases in stock, while the increase in overseas trading necessitated the holding of larger stocks abroad. Exports have again created a record and were considerably in excess of the target figures fixed by the Government. Extensions are in course of construction at the heavy electrical and mechanical engineering works in order to cope with the demand for capital goods, and considerable progress is being made in plant re-equipment. This expenditure, coupled with the increased export business and the large volume of stock and work in progress, has meant a heavy drain on financial resources. Further considerable capital expenditure has been authorised by the board. The number of employees at March 31 last was approximately 54,000.

Whitehead Iron & Steel Company, Limited (MR. G. H. LATHAM):—The year has been an extremely difficult one—shortages of raw material and labour have affected our outputs. Nevertheless, the company has still been able to play its part in the attainment of excellent outputs, and the financial results give every ground for satisfaction. We are contributing very largely to the export trade from all our works. When the Government finds it possible to increase the export allocation of steel in various forms, we hope still further to increase our contribution.

Hick, Hargreaves & Company, Limited, engineers and ironfounders, of Bolton (MR. D. D'ARCY MADDEN):—The British Electricity Authority continues to be our principal customer and orders on our books for condensing plant and feed-heating equipment include plant for the programme year 1953 and exceed in capacity 1,200 M.W. The other departments of the works also have work in hand for many months ahead. While the order-book to-day is undoubtedly satisfactory, new orders are fewer and more difficult to secure and the prices obtainable are less remunerative.

Newman & Watson, Limited, sanitary and heating engineers (MR. B. W. MASON):—The total turnover of the group exceeded £1,000,000. Although output remained at a high level, there was a drop in sales compared with the previous year. Orders obtained in the six months to June 30 are equal to the rate of turnover for 1948-49. It is proposed to amend articles to permit directors' fees to be increased. Continued expansion is fully employing the company's liquid resources. The necessity of increasing the capital is being kept constantly under review.

Personal

MR. S. A. MCCREERY has retired after 48 years' service with Ransomes & Rapier, Limited, engineers and ironfounders, etc., of Ipswich. He was secretary of the company for 26 years.

MR. N. H. KNIGHT, of Alex. M. Ross, iron and steel merchants, Sydney, has arrived in this country. His London address is c/o A. G. Kidston & Parker, Commonwealth Bank Chambers, 10, Old Jewry, E.C.2.

MR. T. M. HERBERT, M.A., has been appointed Director of Research to the Railway Executive. Mr. Herbert is well known to foundrymen through his services on the Council of the British Cast Iron Research Association.

MR. JAMES P. ASQUITH, assistant works manager of the Elswick (Newcastle-upon-Tyne) works of Associated Lead Manufacturers, Limited, has been appointed a director and general manager of a new subsidiary company in South Africa.

MR. A. H. REDFERN has resigned from the board of Vab Products, Limited, brassfounders, of Kingsway, London, W.C.2. MR. J. E HODGKIN has been appointed chairman, and MR. W. G. F. WESTBROOKE and MR. P. J. KIRKMAN have been appointed directors of the company.

MR. T. W. BROWN figures in the announcement of recent appointments by the Railway Executive; he is to be Materials Inspection Officer. For 18 years he was in charge of the testing department at Crewe and was later promoted head of the central inspection bureau of the old London Midland and Scottish Railway.

DR. A. J. KESTERTON has been appointed melting-shop manager at the Abbey Works of the Steel Company of Wales, Limited. He was previously with Dorman, Long & Company, Limited, where, after being melting-shop manager at the Redcar Works, he was seconded for special duties on the design and layout of the new Lackenby steel plant.

MR. W. TAIT, of Stone-Wallwork, Limited, has just returned to this country after making an extensive business tour of South Africa. He visited the Rand, where at Johannesburg he took part in a meeting of the South African Branch of the Institute of British Foundrymen, and later went up to Rhodesia. Here he was received by Mr. Issells, the leading foundry owner of Bulawayo. He was impressed by a statement that the Crown Mines use more electricity than Glasgow, which, if correct, is truly amazing.

PROF. M. L. E. OLIPHANT is to relinquish the office of Vice-Principal of Birmingham University on September 30, although he will continue to occupy the Poynting Chair of Physics. Other changes in the University's staff include the appointments of DR. F. MORTON, a Reader in the Department of Chemical Engineering, to the Second Chair of Chemical Engineering in succession to DR. STACEY WARD, who was recently appointed to the Chair of Mining in the University, and MR. ALFRED JOHN MURPHY as Professor of Industrial Metallurgy in succession to PROF. LESLIE AITCHISON, whose retirement, on the grounds of ill-health, was announced earlier in the year.

The Man with the £500 hands

Why so valuable? They are the hands of a highly skilled electrician who takes pride in his work. He is typical of the thousands of reliable technicians employed all over the country by members of the Electrical Contractors Association. The confidence shown by both Employer and the Association in maintaining this high standard is reflected in the clear-cut guarantee of £500, offered in conjunction with the N.E.C.T.A., against faulty materials and workmanship which every contract carries. From the simple fitting of a lamp to the most complicated wiring specification your best interests will be served by calling in a member of the E.C.A.

Current Prices of Iron, Steel and Non-ferrous Metals

(Delivered, unless otherwise stated)

August 17, 1949

PIG-IRON

Foundry Iron.—No. 3 IRON, CLASS 2:—Middlesbrough, £10 4s.; Birmingham, £10 0s. 6d.

Low-phosphorus Iron.—Over 0.10 to 0.75 per cent. P, £11 15s. 6d., delivered Birmingham. Staffordshire blast-furnace low-phosphorus foundry iron (0.10 to 0.50 per cent. P, up to 3 per cent. Si)—North Zone, £12 2s. 6d.; South Zone, £12 5s.

Scotch Iron.—No. 3 foundry, £11 18s. 3d., d/d Grangemouth.

Cylinder and Refined Irons.—North Zone, £12 14s. 6d.; South Zone, £12 17s.

Refined Malleable.—P, 0.10 per cent. max.—North Zone, £13 4s. 6d.; South Zone, £13 7s.

Cold Blast.—South Staffs, £15 16s. 6d.

Hematite.—Si up to 2½ per cent., S & P over 0.03 to 0.05 per cent.; N.-E. Coast and N.-W. Coast of England, £11 16s. 6d.; Scotland, £12 3s.; Sheffield, £12 9s.; Birmingham, £12 15s.; Wales (Welsh iron), £11 16s. 6d.

Spiegeleisen:—20 per cent. Mn, £17 8s.

Basic Pig-iron.—£9 17s. 6d., all districts.

FERRO-ALLOYS

(Per ton unless otherwise stated, basis 2-ton lots, d/d Sheffield works.)

Ferro-silicon (6-ton lots).—20/30 per cent., £25 15s.; 40/55 per cent., £32 10s.; 70/85 per cent., £49.

Ferro-vanadium.—35/50 per cent., 15s. per lb. of V.

Ferro-molybdenum.—70/75 per cent., carbon-free, 6s. 5d. per lb. of Mo.

Ferro-titanium.—20/25 per cent., carbon-free, 1s. 3½d. lb.

Ferro-tungsten.—80/85 per cent., 7s. lb.

Tungsten Metal Powder.—98/99 per cent., 8s. lb.

Ferro-chrome.—4/8 per cent. C, £60; max. 2 per cent. C, 1s. 5d. lb.; max. 1 per cent. C, 1s. 5½d. lb.; max. 0.15 per cent. C, 1s. 6½d. lb.

Cobalt.—98/99 per cent., 12s. lb.

Metallic Chromium.—96/98 per cent., 5s. 1d. lb.

Ferro-manganese (blast-furnace).—78 per cent., £25 3s.

Metallic Manganese.—94/96 per cent., carbon-free, 1s. 9d. lb.

SEMI-FINISHED STEEL

Re-rolling Billets, Blooms and Slabs.—BASIC: Soft, u.t., £16 16s. 6d.; tested, up to 0.25 per cent. C (100-ton lots), £17 1s. 6d.; hard (0.42 to 0.60 per cent. C), £18 16s. 6d.; silico-manganese, £23 19s.; free-cutting, £20 1s. 6d. SIEMENS MARTIN ACID: Up to 0.25 per cent. C, £22 4s.; case-hardening, £23 1s. 6d.; silico-manganese, £26 6s. 6d.

Billets, Blooms and Slabs for Forging and Stamping.—Basic, soft, up to 0.25 per cent. C, £19 16s. 6d.; basic, hard, over 0.41 up to 0.60 per cent. C, £21 1s. 6d.; acid, up to 0.25 per cent. C, £23 1s. 6d.

Sheet and Tinplate Bars.—£16 16s. 6d.

FINISHED STEEL

Heavy Plates and Sections.—Plates, ship (N.-E. Coast), £20 14s. 6d.; boiler plates (N.-E. Coast), £22 2s.; chequer plates (N.-E. Coast), £22 19s. 6d.; heavy joists, sections and bars (angle basis), N.-E. Coast, £19 13s. 6d.

Small Bars, Sheets, etc.—Rounds and squares, under 3 in., untested, £22 6s.; flats, 5 in. wide and under, £22 6s.; rails, heavy, f.o.t., £19 2s. 6d.; hoop and strip, £23 1s.; black sheets, 17/20 g., £28 16s.

Alloy Steel Bars.—1-in. dia. and up: Nickel, £35 6s. 6d.; nickel-chrome, £49 18s. 6d.: nickel-chrome-molybdenum, £55 0s. 9d.

Tinplates.—I.C. cokes, 20 × 14, per box, 41s. 6d., f.o.t., makers' works.

NON-FERROUS METALS

Copper.—Electrolytic, £107 10s.; high-grade fire-refined, £107; fire-refined of not less than 99.7 per cent., £106 10s.; ditto, 99.2 per cent., £106; black hot-rolled wire rods, £116.

Tin.—99 to under 99.75 per cent., £569; 99.75 to under 99.9 per cent., £572 10s.; min. 99.9 per cent., £577.

Zinc.—G.O.B. (foreign) (duty paid), £63 10s.; ditto (domestic), £63 10s.; "Prime Western," £63 10s.; electrolytic, £64 5s.; not less than 99.99 per cent., £65 15s.

Lead.—Good soft pig-lead (foreign) (duty paid), £87 5s.; ditto (Empire & domestic), £87 5s.; "English," £88 15s.

Zinc Sheets, etc.—Sheets, 10g. and thicker, ex works, £77 10s.; rolled zinc (boiler plates), ex works, £75 10s.; zinc oxide (Red Seal), d/d buyers' premises, £63 10s.

Other Metals.—Aluminium, ingots, £93; antimony, English, 99 per cent., £160; quicksilver, ex warehouse, £18 10s.; nickel, £224.

Brass.—Solid-drawn tubes, 19½d. per lb.; rods, drawn, 10½d.; sheets to 10 w.g., 16d.; wire, 16½d.; rolled metal, 14½d.

Copper Tubes, etc.—Solid-drawn tubes, 19½d. per lb.; wire, 144s. 9d. per cwt. basis; 20 s.w.g., — per cwt.

Gunmetal.—Ingots to L.G.2 (85/5/5/5), £76 to £90; L.G.3 (86/7/5/2), £80 to £118; G1 (88/10/2), £125 to £156 per ton, delivered.

Phosphor-bronze Ingots.—P.Bl, £126 to £170; L.P.Bl, £88 to £118 per ton.

Phosphor Bronze.—Strip, 22½d. per lb.; sheets to 10 w.g., 24½d.; wire, 24½d.; rods, 23d.; tubes, 27½d.; chill cast bars: solids, 23d., cored, 24d.; 10 per cent. phos. cop., — ; 15 per cent. phos. cop., — ; phosphor tin (5 per cent.), — . (C. CLIFFORD & SON, LIMITED.)

Nickel Silver, etc.—Ingots for raising, 1s. 4½d. per lb. (7%) to 2s. 1d. (30%); rolled metal, 3 in. to 9 in. wide, × .056, 1s. 10½d. (7%) to 2s. 7d. (30%); to 12 in. wide, × .056, 1s. 11d. to 2s. 7½d.; to 25 in. wide, × .056, 2s. 1d. to 2s. 9½d. Spoon and fork metal, unsheared, 1s. 9½d. to 2s. 5½d. Wire, 10g., in coil, 2s. 3½d. (10%) to 3s. 0½d. (30%). Special quality turning rod, 10%, 2s. 2½d.; 15%, 2s. 7d.; 18%, 2s. 11d.

News in Brief

BORAX & CHEMICALS, LIMITED, announces further reductions in the prices per ton for "Three Elephant" brand commercial granulated borax and "Pyrobor" (dehydrated borax) to £27 and £46 respectively.

J. BROCKHOUSE & COMPANY, LIMITED, of West Bromwich, has acquired control of B.M.S., Limited, of South Africa, the name of which may be changed in the near future. Park Royal Vehicles, Limited, of London, will retain its interest.

BORAX CONSOLIDATED, LIMITED, announces a reduction in its prices for "Twenty Mule Team" brand granular borax, commercial quality, and dehybor (anhydrous borax), new prices being £27 and £46 per ton, in bags, delivered buyer's address Great Britain in 1-ton lots and upwards.

HECTOR WHALING COMPANY, LIMITED, has acquired the majority of the holdings in Gearings (1947), Limited, and Jameson's Premier Engineers, Limited, both of Capetown. The two firms will now be amalgamated and be known as Gearings & Jameson, Limited. Extensions to the engineering shops and foundries are envisaged.

PRODUCTION IN THE £1,000,000 extension of the General Electric Company, Limited, at Witton, which will add 100,000 sq. ft. of space to the works, will start next March. The main part of the extension is a huge constructional shop in which the largest size of generator likely to be required for many years can be built.

MR. THOMAS URIE, melting-shop supervisor at the Dalzell Works, Motherwell, and MR. RONALD S. KEITH, assistant fuel officer at the Clydebridge Works, Cambuslang, of Colvilles, Limited, are to exchange jobs with two French steelworkers under the British Iron and Steel Federation's scheme for the exchange of overseas personnel.

Obituary

MR. KENNETH HUGH MUNRO CONNAL, chairman of Connal & Company, Limited, pig-iron and metal warehouse keepers, of Glasgow, died on Saturday.

MR. JOHN MCKECHNIE, who died suddenly recently, was secretary of the Mirrlees Watson Company, Limited, engineers and ironfounders, of Glasgow, for almost 20 years. He had previously been assistant secretary. Mr. McKechnie joined the firm as a junior clerk in 1906.

MR. CHARLES L. BURDICK, founder of the Aerograph Company, Limited in 1900, has died in California at the age of 86. He developed an artist's air-brush as long ago as 1893 and later concentrated on industrial spray-painting equipment, in which field he was responsible for numerous inventions.

MR. WILLIAM H. FRENCH died on Wednesday of last week at the age of 70. Mr. French had been associated for 55 years with T. & C. Clark & Company, Limited, Shakespeare Foundry, Wolverhampton, becoming secretary in 1916 and a director in 1934. He was connected specially with the London interests of the firm.

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NOTICE

Small Advertisements in this section of the Journal are accepted at the *prepaid* rate of 20 words for 5/- (minimum charge) and 2d. per word thereafter. Box number advertisements 2/- extra. Instructions together with remittance must be received not later than first post on Friday for inclusion in Thursday's issue addressed to the Advertisement Manager, Foundry Trade Journal, 49 Wellington St., London, W.C.2.

Situations advertised under this heading are available only to applicants excepted from the Control of Engagement Order, 1947, No. 2021.

Replies to Box Numbers to be addressed to:— "Foundry Trade Journal," 49, Wellington Street, London, W.C.2.

SITUATION WANTED

PATTERNMAKER, Rate Fixer and Planner seeks position with Engineers; experience general patternmaking, foundry mechanisation; at liberty about the middle of November, after completing work abroad.—Box 218, FOUNDRY TRADE JOURNAL.

SITUATIONS VACANT

APPLICATIONS are invited for the appointment of SALES MANAGER, in the Light Castings Department of Newton, Chambers & Co., Ltd.

The duties will involve responsibility for sales policy and organisation; control of representatives, and publicity.

Applicants must possess up-to-date knowledge of modern fuel-burning appliances.

Please apply, stating age, experience, education, and salary required, to the PERSONNEL OFFICER, Newton, Chambers & Co., Ltd., Thorncliffe, near Sheffield.

APPLICATIONS are invited from young Foundrymen, between the ages of 25 and 30, with a sound metallurgical education, for the post of ASSISTANT CHIEF METALLURGIST, in a large and vigorous Foundry organisation centred in the Midlands; practical experience of metallurgical control and investigation in both laboratory and foundry is essential; ability to deal with external problems and queries is highly desirable; the position, which is superannuated and a staff post, carries a minimum commencing salary of £450 per annum, according to foundry experience and qualifications.—Box 222, FOUNDRY TRADE JOURNAL.

SITUATIONS VACANT—*Contd.*

AN old-established Firm of Non-ferrous Founders in the Croydon area, specialising in jobbing and repetition work, have a number of vacancies for Skilled MOULDERS.—Application, stating age and experience, to Box 966, FOUNDRY TRADE JOURNAL. This advertisement appears by permission of the Ministry of Labour and National Service under the Control of Engagement Order, 1947.

CORESHOP FOREMAN required for light alloy foundry in Birmingham area. Must be conversant with up-to-date methods, including core-blowing, and capable of handling mixed labour. Able to fix prices and read blueprints.—Reply, stating age, experience, and salary required, Box 232, FOUNDRY TRADE JOURNAL.

ENAMEL TECHNICIAN required; man with knowledge enamel manufacture and application, including dry process, and with supervisory experience.—Applications, which will be treated confidentially, should be made to Box 208, FOUNDRY TRADE JOURNAL.

ENAMELLING FOREMAN to take complete charge of Vitreous and Synthetic Enamelling of Domestic Products, using mechanised plant.—State age, experience, present position and salary. Box 224, FOUNDRY TRADE JOURNAL.

EXCELLENT opportunity energetic practical FOUNDRYMAN, preferably already calling trade, sell new proposition interesting all foundries.—Box 952, FOUNDRY TRADE JOURNAL.

FIRM in the Midlands building new Foundry invite applications for the post of FOUNDRY MANAGER. Applicants should have knowledge of modern foundry layout and metallurgy with first class experience of the production of high quality castings in magnesium and other non-ferrous metals.—Applications, stating experience, age, and salary required, to Box 230, FOUNDRY TRADE JOURNAL.

FIRST-CLASS CHEMIST wanted; used to manufacture of non-ferrous ingots; able to supervise and makecharges; good position for first-class man.—Box 216, FOUNDRY TRADE JOURNAL.

FIRST-CLASS COMMERCIAL MANAGER required, to take charge of Non-ferrous Foundry Business in Calcutta; British interests; manufacturing alloys, castings and ingots; salary of £2,000 per annum, plus share of profits, will be paid to right man.—Applications to: SECRETARY, J. Stone & Co., Ltd., Deptford, London, S.E.14.

WORKING CHARGEHAND required for bronze chill bar casting; scope and good prospects for capable man of proved ability.—Box 238, FOUNDRY TRADE JOURNAL.

SITUATIONS VACANT—*Contd.*

FOUNDRY FOREMAN for Jobbing Foundry, West Riding, Yorks.; 10 tons per week; must be capable of stepping up production.—Write, stating experience, age and salary required.—Box 190, FOUNDRY TRADE JOURNAL.

LARGE Heavy Industrial Concern in Midlands have the following vacancies for permanent progressive posts. Pensions Scheme in operation. Salary in accordance with qualifications:—

SENIOR MAINTENANCE FOREMAN. To organise and control Maintenance Dept., Machine Shop, etc., and set high mechanical standard. Must have steelwork or similar heavy industrial experience with mechanical plant, cranes, compressors, air mains, etc. Good organiser and disciplinarian essential.

SENIOR PLANT DRAUGHTSMAN. To lay out and design heavy mechanical plant, conveyors and handling equipment. Good mechanical, structural and civil engineering experience essential.

SENIOR ELECTRICAL DRAUGHTSMAN. To lay out and specify equipment for sub-station, distribution, control gear, cranes, lighting, etc. Must be able to work on own initiative and have previous experience in high-class work.

Reply to Box 4186, SCOTTS, 9, Arundel Street, London, W.C.2.

METALLURGICAL CHEMIST required; to take charge of cupola control, ferrous foundry, South London; state experience and salary required.—Box 212, FOUNDRY TRADE JOURNAL.

REQUIRED.—Thoroughly experienced PATTERNMAKERS (Wood and Metal) and IRON MOULDERS.—Apply personally to H. C. HOPPER (KINGSTON), LTD., 65, Hampden Road, Kingston-on-Thames.

REPRESENTATIVE for Yorkshire, Lancashire and North, on commission basis, required by Midland Ironfoundry producing small Malleable and Grey Iron Castings.—Box 210, FOUNDRY TRADE JOURNAL.

REPRESENTATIVE required for the Sale of Industrial Leather Gloves and Aprons; must have sound connection amongst large users.—Write, in confidence, to J. MOON & SON, 94, Sclater Street, London, E.1.

TWO vacancies for Graduates have arisen on the staff of the Research Laboratories of The General Electric Co., Ltd., East Lane, North Wembley, Middlesex: (*a*) WELDING METALLURGIST, preferably with experience of work on the metallurgical aspects of welding; (*b*) METALLURGIST, to investigate problems relating to heat-resisting surfaces, including the fundamental study of the diffusion of metals in the solid state.—Applications should be addressed to the PERSONNEL OFFICER, giving age, qualifications and experience.